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Plateaus and the Curve of Learning in Motor Skill

BY

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I. REVIEW OF LITERATURE

During the past forty years, learning curves have been the subject of a considerable number of studies. A survey of the literature discloses that there are two main classes of curves commonly included in the term "learning curve": first, the practice curve for acquiring some kind of motor skill, and second, the curve of memorizing material such as nonsense syllables.

We shall be concerned with studies of the practice curve in the acquisition of some kind of motor skill. Different factors that influence improvement in the course of learning have occupied the attention of investigators. Several different features of the learning curve have been isolated and attempts to interpret them have been numerous. Of all the features which have been found in practice curves of skill, none has been so puzzling as the periods of non-progress which are commonly called "plateaus". It is to this particular problem that attention is specifically directed in the present study.

Batson (1) made an elaborate study of the acquisition of motor skill. We may refer to his monograph for a review of the literature up to the time he wrote. His aim was to study the cause of plateaus and to find out whether they are necessary for all or any types of learning. He performed three sets of experiments: (a) one to test the effect on the form of the learning curve of a number of factors working simultaneously, (b) another to find the form of the learning curve for simple sensory motor learning, and (c) a third to observe the effect on the learning curve of several factors operating in succession.

For the purpose of studying several factors influencing learning simultaneously, Batson had subjects toss and catch two balls so that one would be always in the air, some subjects with special direction to pay attention to one particular feature and others to

attend to the whole act. In most cases each practice day consisted of ten trials and each trial of as many catches as one could make before missing the ball. Curves were plotted having the divisions on the x-axis represent practice periods and those on the y-axis number of catches made on the day. In one case the number of catches in every ten trials was grouped. In two cases, where the subject continued practice each day until he had made a definite number of catches (in one case one hundred and the other five hundred), the reciprocals of number of trials necessary in order to make the required number of catches were plotted on the y-axis and the practice periods on the x-axis. Again curves were plotted by taking groups of one thousand tosses for the x-axis and the average number of catches per trial for divisions on the y-axis. Another group of curves was plotted by dividing the catches into groups of one thousand each, and then finding what percentage each thousand catches was of the total number of tosses for making one thousand catches.

All the curves in this part of the study, when based upon average catches per "trial", were concave to the y-axis, that is, showing a slow rise at first and a rapid rise at the end. The same material, plotted so as to give the percentage that catches are of total tosses, showed curves convex toward the y-axis. In none of the curves was there any evidence of a plateau. In this respect his results in the experiment on ball tossing resembled those of Swift.

In order to study the nature of improvement in simple learning, Batson used the elements of direction, force, and time separately. For direction, a line was drawn across a smooth board at right angles to the side, 40½ inches from one end. Inch spaces were marked on this line and numbered from zero in the center to positive 7 on one side and to negative 7 on the other. Seven and one-half feet from the line, another line was drawn across the board and parallel to the first. The board was 3½ inches higher at the first line than at the second. A wooden block was set at the zero mark. The subject, standing at the lower line, rolled a steel ball one inch in diameter and 66.8 grams in weight toward the block, and a record was made of the mark

at which the ball passed on the higher line. Curves were obtained by representing the total score for each day's practice, along with the total number of actual hits on the y-axis and practice periods on the x-axis. Two subjects took part in this experiment.

In studying force, Batson placed on a table a board with a point marked zero elevated 3½ inches above the mark from which a ball (in one case of rubber and in another of steel) was to be thrown. At the zero mark he drew a heavy line across the board. On both sides of this line he laid off divisions three inches wide by drawing other lines across the board parallel to the line running through the zero mark. These divisions were marked up to positive 13 or 15 on one side and to negative 13 or 15 on the other. The subject stood at a mark parallel to the zero mark and 7½ feet away and tried to throw the ball so that it would roll to the zero mark. A record was kept of the actual mark which the ball reached on either the positive or negative side of the zero mark. The score for each day was found by multiplying the number of each mark reached by the number of times it was reached on the day and adding the products obtained. Curves were plotted by representing the total score on the y-axis and the practice periods on the x-axis.

The third element, time, was studied in the following way. A circular wooden disc was placed in a horizontal plane on a rotating axis and a motor was belted to the axis in such a way that the disc could be rotated. Two concentric rings of cardboard were attached to the upper surface of the disc, 1½ inches apart. The space between them was divided into 12 sections or pockets by tacking pieces of tin along the radii of the disc between the cardboard rings. A trough was so supported that the lower end rested ½ inch above the little pockets and the upper end was 6½ inches higher. A shot was held behind a piece of wood placed in the trough 18 inches away from the lower end, so that when the wood was lifted the shot rolled down through the trough and fell into one of the pockets. One pocket was marked zero. The disc was covered by cardboard from which a sector had been cut, and as the board rotated, the subject

could see the pockets pass under the end of the trough. The task of the subject was to release the shot at such a time that it would roll down through the trough just in time to fall into the zero pocket. The pockets on the two sides of the zero pocket were progressively numbered, positive on one side and negative on the other. Fifty trials were taken each day. The score was counted as follows: the number of shots in each pocket was multiplied by the number of the pocket and the sum of the products taken as the score for the day. Curves were obtained by plotting the daily score on the y-axis and practice periods on the x-axis.

A study of all the curves of these simple learning processes "except in cases where subjects made very high score during the first two or three practices, show a downward slope with considerable daily fluctuation". In none of them are plateaus found.

In order to study the form of the learning curve when several factors were working in succession, that is, when several factors were influencing attention, but in such a way that they could be separated, the following experiment was performed.

An apparatus consisting of a disc 10 inches in diameter supported on an axis was fastened in a horizontal position to a table and three inches above the table. A motor was attached to a pulley, which was underneath the disc. Eight spoon-shaped depressions were carved out on the top of the disc. They were ¾ of an inch long, ½ of an inch wide and ¼ of an inch deep, located ¾ of an inch from the circumference of the disc and 45 degrees between centers. The disc was covered with a cardboard having a sector cut out so that ⅛ of the disc and one spoon-shaped depression were all that were exposed at any one time. Twenty-three inches from the center of the disc and perpendicular to the table was a circular frame made of a hoop covered with cloth. To the center of this was attached another pocket protruding from the side opposite the disc. The middle of this pocket was 8 inches from the table and 5 inches above the level of the top of the disc.

The task of the subject was to seize a shot from each of the eight holes on the rotating disc with a pair of tongs and throw them into the pocket. Record was made of hitting the shots, seizing the shots, hitting the large circle (or frame) and hitting the pocket. Four subjects took part, each having 80 trials daily. Separate curves were plotted for each part process and for each subject. The vertical axis represented the number of shots and the horizontal axis the number of practice periods. In this exercise long period plateaus were found in some curves and not in others, especially when the number that hit the pocket was used as the unit of measure. Batson maintained that analysis of all the curves showed that those subjects who attended to the work in parts showed plateaus in the parts not attended to, and the subject who had no trouble with the first part elements did not have to divide attention and thus no plateaus appeared. From this part of the work he concluded that there may or may not be plateaus of long duration in the same type of work.

From the results obtained in his several sets of experiments, Batson drew the following conclusions:

Regarding the form of the curve he believed "there is no typical curve for all types of learning. Where the work is so simple that attention cannot be distributed the curves are likely to be of a similar form for different subjects. Where the work is complex and attention can be distributed on different parts of the process, then the curves for different individuals vary, though the work is the same". Regarding plateaus, he said, "There is no evidence to show that they (plateaus) ever occur in learning processes where there is only a simple association process. If the factors involved are of such nature that they must be improved together, or if the subject is able to attend to them as a whole, there will be no plateau. If, however, the nature is such that the factors must be attended to in succession or the subject gives his attention to the separate factors as such, there will be plateaus."

Peterson (4), too, studied the learning curve of motor skill by having subjects toss and catch two rubber balls. In his work also, a series ended with the miss of a ball and the subject con-

tinued each practice period until two hundred catches were made. Subjects were divided into two groups, one practicing once a day and the other twice a day. Record was taken in terms of misses in two hundred catches. Curves were drawn of errors and average number of catches per "trial". In his curves he found complete absence of any important plateaus but was not sure that this meant there were no actual plateaus in the learning curve. He felt that perhaps it was the type of curve chosen which might have concealed the plateaus.

Chapman and Hills (2) obtained curves on typewriting over periods of practice of 20–180 hours. In 20 full individual curves they found neither a fundamental typical curve of improvement nor plateaus, but most subjects did show short plateaus which the authors thought were probably genuine.

Trow and Sears (6), studying card sorting, found that plateaus were caused by conflicting methods.

Recently Smith (5) carried out a group of experiments to study further the existence and causes of plateaus in three kinds of learning. The first was a ringball game, a complicated act in which the factors could be separated. Two types of this game were employed. In type one the learning was divided into three sections. The subject first learned to toss a ball into the right hand target ring on the wall and catch it after it had bounced once on the floor. After the subject had caught 16 out of 20, new elements were introduced. Next he learned to throw alternately with the right and left hands making the right hand ball bounce inside a target on the floor. Then he was required to make the other ball bounce into a left hand floor target. Score was taken by allowing one point for each shot that entered each target on the wall, one point for the ball caught on the return, and one point for each ball bouncing inside each floor target. Seven subjects learned the task. Each practice consisted of five sets, and each set consisted of 20 throws when one hand was used and 40 throws when both hands were used.

In the second form of this ringball game, a target of three concentric rings was used in place of the single hit or miss target, and the areas between the rings were painted in different colors.

A specific value was assigned to each ring for the purpose of keeping scores. Each practice consisted of five sets including 20 shots with the right hand and 20 shots with the left hand alternately. Two subjects began practicing the complete movement with both hands, throwing and bouncing, while two others began practicing with right and left hands in successive sets on the same occasion, but not alternately. After six days of practice, these two latter subjects threw alternately with right and left hands and, after 12 practices, tried to make the ball bounce inside the floor target.

Curves were plotted of the total score and of separate elements by plotting on the y-axis the point gained, and on the x-axis the number of practice periods. Smith defined the plateau as a period which does not show progress for six or more practices. In the curves of their total scores all of the nine subjects who took part in this ringball game showed plateaus which Smith called "periods of arrested progress". In addition to those which could be accounted for by accidental factors, the experimenter attributed the plateaus to the following causes which he believed inherent in the learning process for the subject:

1. Concentration on one component of the task. This sometimes improved the component, sometimes not only failed to improve it, but even caused it to deteriorate, making the total score show no improvement.
2. Shift of attention from one to another component irregularly. This caused irregularity in the component scores and non-improvement in the total score.
3. Coördination impeded by conscious attention to it. Over-anxiety interfered with learning.
4. Interaction between two components. When a new factor was introduced after the old one had had some practice, the habits and errors of one crept into the other.
5. Components possibly not in suitable stages for coördination, that is, the component processes were not at equal levels of efficiency, so could not be coördinated, and thus the total score showed no progress.

In his second experiment the subject had to guide accurately and quickly a small metal ball up to the top of an inclined plane by the use of a knitting needle. On the surface there were 21 holes into which a ball might fall on its way up the plane, and interspersed among the holes were small wooden barriers which it was necessary to circumvent. Records were kept of the time taken and of the spot which the ball reached after each attempt.

Ten points were given if the ball went up the plane without any mishap and proportionate points given for different places on the board. Curves were plotted of the average marks of the practice days and the percentages of successful attempts. The curves thus obtained showed several periods of non-progress which the author explained on the basis either of relearning required by break in practice due to vacation, or of concentration on one component, or of having attained the limit of proficiency.

In the third experiment the subject had to practice a phonetic system. The learning problem included first a copy test in which the subject was required to transcribe into shorthand in five minutes words of only one syllable. Then a dictation test was introduced in the 8th practice for five minutes, and finally a speed test, which consisted of repeating a given sentence in shorthand as many times as possible. One point was given for each word correctly written in the copy and dictation tests and for each correct copy of the sentence in the speed test. Curves, made by plotting the scores on the y-axis and the number of practice periods on the x-axis, reveal several arrested periods. These Smith was able to explain again either on the basis of incidental factors, such as the physical or mental state of the subject, distracting noise and relearning after vacational break, or by causes inherent in the learning act, such as difficulty of compounding long words and inability to increase the speed of working.

The causes of plateaus in the curves obtained Smith summed up in the phrase " difficulties of coördination ". " Coördination may be impeded by undue attention to one component task, or by an oscillation of attention from one to the other, or by conscious effort to coördinate. Apart from attention, coördination may be delayed by interaction between components and lastly—coördination may be checked when there is too great a disparity between the proficiencies in the separate components ".[1] He found also that periods of arrested progress were not characteristic of any particular stage in the acquisition of skill but seemed rather to be scattered promiscuously among the curves. A period of non-

[1] Smith. Periods of Arrested Progress in the Acquisition of Skill. *British Journal of Psy.*, Vol. 21, 1930, p. 24.

progress usually terminated in an abrupt but often merely temporary resumption of progress. The author's final conclusion as to the appearance of plateaus was that, when the subject regarded the task as a unit, such periods of plateau probably would not appear, but, when the task was regarded as composed of separate units which could be attended to separately, plateaus would appear in the learning curves and their appearance was due to difficulties in coördinating. Obviously Smith agrees with Batson that, when a task is looked upon as a complex process and attention paid to components separately, there will be plateaus, but when elements are not or can not be separated and attention thus directed, no plateau will appear.

II. STATEMENT OF PROBLEM

The authors reviewed, particularly Batson, suggested that the appearance of plateaus in a curve of learning depends upon the way attention is distributed in the course of learning. That is, if the task is of such nature that the separate parts can not be singled out for special attention, there will be no plateau; but, if a complex task is such that the components can be attended to separately and the learner chooses to do so, there will be plateaus in the learning curve. The purpose of the present study is to test this suggestion of Batson. That is, this investigation purports to:

1. Study the appearance of plateaus in learning curves of a simple motor skill as compared with those in curves of complex motor skill, and

2. Compare the appearance of plateaus in a learning curve of a complex skill in which the factors work simultaneously and are independent of one another with the appearance of plateaus in a curve of a complex skill in which the factors work in succession and where the successive parts are dependent upon one another; and, in both of these situations, to compare the curve for a learner who has knowledge of the separate parts of the complex task with the curve for one who knows nothing of the separate parts before beginning to learn the complex skill.

For the above purpose two motor skills have been employed. In order to make a curve of simple learning and a curve of complex learning directly comparable, the component parts of the complex task have been taken as the tasks for simple learning. Two types of experiments have been undertaken: in one the components were independent of one another; in the other one factor was dependent upon the other. Those experiments were carried out in the academic years 1931–1932 and 1932–1933.

III. TYPE I—EXPERIMENTS

COMPLEX MOTOR SKILL

COMPONENTS OPERATING SIMULTANEOUSLY AND INDEPENDENTLY

A. DESCRIPTION OF APPARATUS

For experiments of Type I, numbers 1, 2, 3, and 4, a single apparatus was used. This apparatus was so constructed that, in the complex skill to be acquired, the elements which operated simultaneously when practiced in the total complex, could be rendered independent of one another and could be learned either separately as simple skills or together as the single complex skill.

Figure I shows the set up of the apparatus. It was designed by Professor J. F. Shepard for use in several studies of acquisition of skill. A framework supports a horizontal shaft of 51 inches in length and 47 inches above the table. (T) is a steel band in the form of an arc 39½ inches in radius. It swings about the horizontal shaft as an axis by means of a hub. The arc is attached to the hub by means of a cross-beam and two straight supports. It is balanced by a counterweight attached to the cross-beam above. The position of this weight determines the speed of the arc when swinging as a pendulum. On the middle section of the arc 19 leather vanes ½ inch wide and 1½ inches long are hinged adjacent to each other in such a way that they fall backward on being hit. The middle one of the vanes is colored black and marked zero, while the others are colored yellow and marked one to nine positive and negative from the center out to the right and left. The arc, when not in use, is hooked in a trigger set in a wooden rest. When in this position the distance between the "zero vane" on the arc and a suspended pendulum (to be described later) is 24½ inches. This arc with

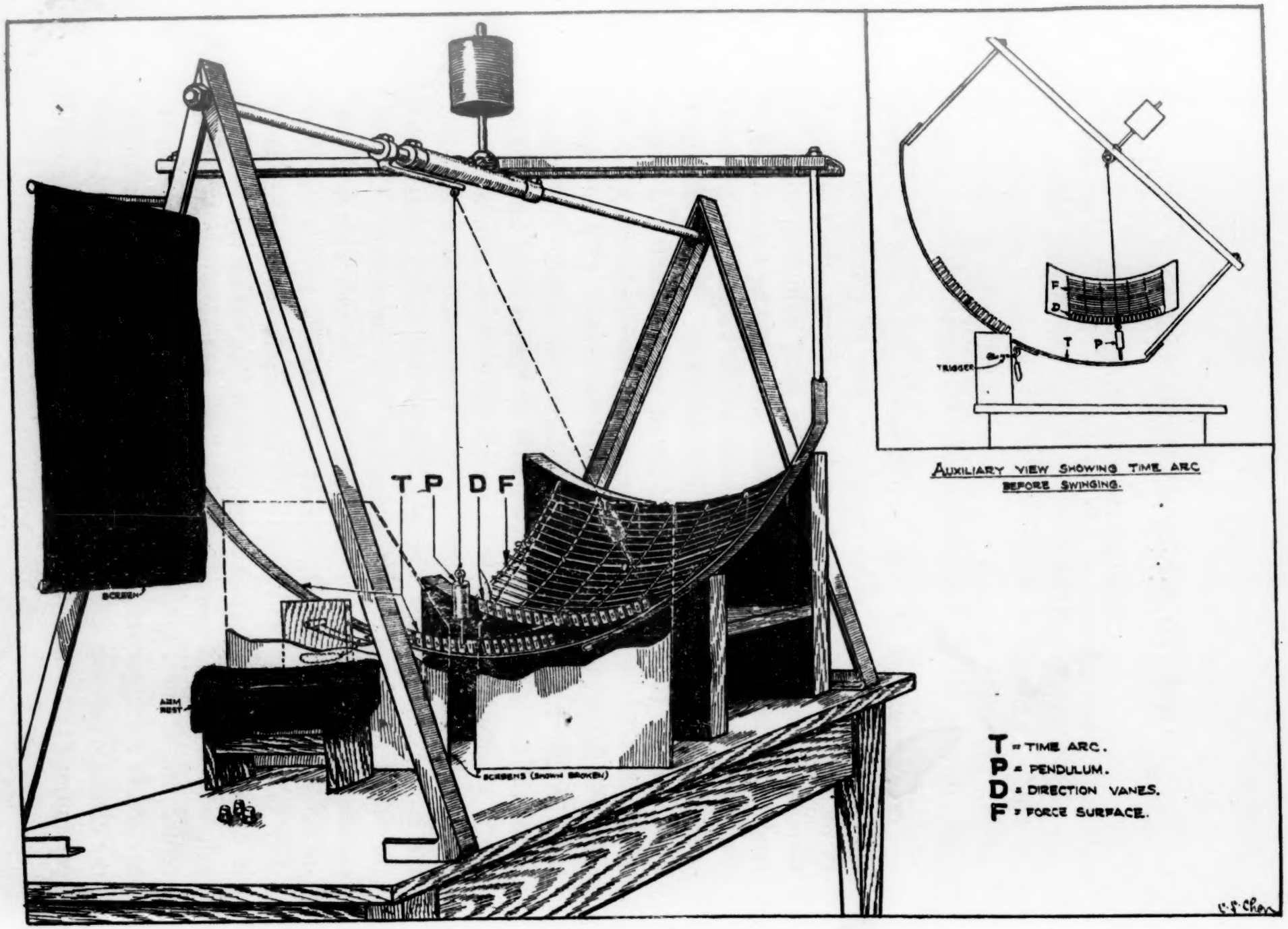
T P D F
SCREEN
ARM REST
SCREENS (SHOWN BROKEN)
F
P
T
P
TRIGGER
AUXILIARY VIEW SHOWING TIME ARC BEFORE SWINGING.
T = TIME ARC.
P = PENDULUM.
D = DIRECTION VANES.
F = FORCE SURFACE.
C.S. Chen

FIGURE I

its leather vanes will henceforth be referred to as the "time arc" and the leather vanes will be referred to as the "time units". When set in motion as a pendulum, the frequency of this time arc is 10 complete periods per minute.

One inch in front of the lowest point in the path through which the arc swings, a cylindrical weight is suspended from the shaft on a non-stretching thread 34¾ inches long. This will hereafter be spoken of as the pendulum (P).

(D) is an arc cut out on a wooden stand. This arc is part of a circle which has its center in the shaft at the point of suspension of the pendulum and is placed at a distance of 11 inches behind the pendulum weight. Directly behind the pendulum on arc D is a series of leather vanes of the same dimensions as those on the time arc. The central vane is black and is marked zero. To the right and left of this zero vane are nine others marked one to nine positive and negative. This portion of the apparatus will be called the "direction arc" in the following discussion.

(F) is a force index surface which is affixed to the wooden stand behind the direction arc. This force index surface is spherical in form, consisting of a network of wires. Fifteen colored wires spaced horizontally at equal distances are supported at suitable intervals. They form such a part of a spherical surface that any two points on any one of these horizontal lines are equidistant from the resting position of the pendulum. The middle heavy line is colored white and marked zero and the others above and below are marked one to seven positive and negative respectively.

In a vertical plane parallel to and ½ inch from the time arc two cardboard screens are set up in such a way that they cut off the view of the ends of the time arc, but leave the direction arc and the force index surface visible to the subject, who sits at the table with his left arm on the arm rest immediately in front of the screen. When the hand is held in front of the pendulum with the palm side toward the apparatus, it covers the time arc as the latter moves past.

B. EXPERIMENT 1

Time (Simple Skill)

a. *Procedure*

In this experiment the task was to learn to estimate time. The subject sat comfortably at the table with his left arm on the arm rest and hand palm-side inward in front of the pendulum. The operator sat behind the cardboard screen. At the signal of "ready" the operator released the time arc from the trigger and this produced a click. The subject, after hearing the click, had to estimate the length of time necessary for him to wait before pushing the pendulum with the tip of the fourth finger so that it would hit the zero mark on the time arc as the latter passed before him. After each trial the operator reported to the subject the actual mark hit as, for example, +8 or −9, and recorded the same. This was done for 100 trials each day. Six subjects took part in the experiment. Three of them—K, L and W—who learned the skill in the school year 1931–1932, practiced on alternate days or three times a week, and with the active finger uncovered. The other three subjects—H, Kl and Ws—practiced five times a week on successive days and wore an aluminum thimble on the active finger. They were required to hit the pendulum with the tip of the thimble. The first three subjects were graduate students, K specializing in psychology, and L and W taking courses in the field. The other three subjects were members of the class in general experimental psychology, and these learned the skill in the academic year 1932–1933. Each subject came at a regular hour each time and five minutes were taken for rest after the 50th trial. The score for the day for each individual was obtained by adding arithmetically all the scores made during the practice period and finding the average per trial.

The results of this experiment are presented in curves I–VIa. These curves were plotted by making the divisions on the x-axis represent the practice periods and the divisions on the y-axis represent the average scores.

b. *Discussion of Results*

Most of the learners began with random trial and error procedure and were interested primarily in the scores they made. Very little attention was given to such details as placing the hand in the most comfortable position and hitting the pendulum so that it would not swing about in all directions. These items were taken into consideration later as learning progressed. The most important factor in this learning activity seemed to be concentration of attention. Anything that distracted attention had a detrimental effect. This was especially true at the beginning when any noise from outside tended to interfere with concentration on the task. All subjects started out estimating time by the method of counting. At first they selected a number arbitrarily and then changed it according to whether the stroke proved to have been made too early or too late. After some periods of practice (the number varying for different subjects), most of them gave up counting and tried just to get a feeling for the time needed. This took place early for subjects L, W, Ws, and K, but never did occur in the case of subject H. For all subjects, though to a less degree in the case of H, the estimation of time to hit became automatic with practice and finally was done with very little effort. Most of them said that they simply listened for the click and, after an interval, the finger seemed to hit the pendulum of its own accord. Many of them had previous training in activities which required more or less precision in time. Some were trained in music, others had done other types of work requiring fair judgment of time.

A study of the curves of time shows that they have the general characteristic of falling rapidly at the beginning and then more slowly with continued practice. The curves for L, W and Ws show better progress at the beginning than the others but, generally speaking, in every case improvement was more rapid at first and gradually slower as learning approached the limit of which the individual was capable. The curves for K and Kl show the initial plateau which often occurs in curves of learning.

Curve Ia gives the course of learning for subject K. As stated above, there is an initial plateau. The high point on the fourth practice was caused by giving up counting and trying to estimate time directly. Counting was found to be inaccurate because speed of counting is not constant, and K decided to try determining time by direct estimation. He took occasion to return to counting several times, and this changing of methods accounts for the slow improvement made up to the 14th practice. After this, learning improved gradually until the end.

Curve IIa represents the learning of subject L who was quite well trained in music. After the first rapid progress, due to getting acquainted with the apparatus and the whole experimental situation, her learning proceeded with gradual improvement. She gave up counting a few days after beginning to work.

Curve IVa represents the learning of H who kept counting until the very end. Periods 5–10 seem to show less improvement than other parts of the curve. This was due to constant change in method of counting. H had to try counting several different numbers before one definite mode of counting was finally adopted. After this period his curve showed a downward trend also.

Curve Va, like Ia, does not show as rapid progress at the beginning as do some of the others. This subject (Kl) adopted the method of counting and kept it up until he was well along in the course of learning and had developed a sense of the time interval. His learning was more gradual from beginning to end with daily fluctuations, although improvement was somewhat faster at the very beginning.

Subject Ws, whose learning is shown in curve VIa, also gave up counting quite early in the course of learning. His progress was rapid at the beginning but slowed down after the 7th trial, with improvement gradually decreasing thereafter. The work became natural and more or less mechanical quite early for him. Periods 12–16 show slower progress than other parts of the curve which, judging from introspections written at the time, must have been due to anxiety. A week of tests in other school work

and lack of sleep caused poor results on the first day. When the subject came back the following day he remembered that he had done poorly the day before and was determined to do better. He applied unusual effort but the results remained poor and, the harder he tried, the poorer the results seemed. This continued throughout the week. He could not tell why he could not make better scores than he did. The next week school tests were over, he was taking life more easily, and his experimental results also improved. This is an instance in which anxiety, which the subjects themselves thought of as greater concentration of attention, doubtless entered in to impede progress.

In almost all the curves there was a downward slope toward the very end of learning. Probably this was due to extra effort at the end to see if one could not improve further even though the preceding scores had been fairly good. In general, the curves do not show any long periods of non-progress which are known as plateaus, but factors of over-anxiety and shifting of methods did slow down improvement at times. The differences in the distribution of practice did not seem to have any appreciable effect on the form of the curve. As was expected, the fact that the one group of subjects did not wear a thimble while the other group had to hit the pendulum with the tip of the thimble made no difference. The element under study was timing, and the pendulum was hanging so close to the arc that there was no need of hitting the pendulum hard and so there was no danger of slipping.

C. EXPERIMENT 2

Direction (Simple Skill)

a. *Procedure*

Using another part of the same apparatus, the subjects learned to judge direction. Again the learner sat comfortably at the table with his left arm on the arm rest and his hand palm-side inward toward the apparatus. Using the tip of the fourth finger, at the signal of " ready ", he tried to strike the pendulum so that it would hit the zero mark on the direction arc. After

each trial the mark actually hit was reported to the subject and recorded by the operator. Each subject was allowed 100 trials per day and five minutes were taken for rest after the 50th trial. The same individuals who served as subjects in the experiment on time served also in this one. As before, three of them—K, L and W—had three practice periods per week and practiced without wearing the thimble, while the other three—H, Kl and Ws—practiced five successive days per week with the thimble on the active finger. Each subject came at a regular hour for each practice.

The score of the day for each subject was obtained by the method used in the time experiment, that is, by finding the arithmetical average per trial of all the marks made during the practice period. Curves I–VIb give the results of this experiment. These curves were plotted with the divisions on the x-axes representing the practice periods and the divisions on the y-axes representing the average scores.

b. *Discussion of Results*

The task was not of equal difficulty for the two groups of subjects. One group—K, L and W—hit the pendulum with the finger itself, while the other group hit it with the tip of the aluminum thimble. The subjects without the thimble could get the feel of pushing the pendulum and there was little danger of it slipping away from them, but for the subjects wearing the thimble there was not so fine a sense of feeling in the finger and the pendulum was likely to slip in all directions whenever it was not hit on just the right spot. It should be pointed out here that the thimble was introduced in the second year, because, after the first year's work, it was apparent that the tasks of direction and force (to be described later) were too easy and something needed to be done to make them a little more difficult. As the results indicate, the first group of subjects started at a lower level of error than the second. Naturally there were individual differences within each group due to differences in aptitude and in past experience. Subject K had much experience in sports, such as tennis, basketball and handball, all of which require fairly good

judgment of direction. The curve (Ib) of his results shows that when he started the learning of this skill his errors were much lower than those of Subject L (Curve IIb) of the same group, although he did show considerable improvement with practice. Subject W also enjoyed sports and games. Her scores, too (Curve IIIb), show that judging direction was not as hard a task for her as it was for Subject L. On the first day her score was not as good as that of Subject K, but after the 10th practice she reached a lower level of error than he. This probably was due to the fact that she had had more occasion to use her fingers in fine skilled work and was better able to get a fine sense of feeling in the finger tip when she did hit the pendulum just right than was Subject K. Subject L (Curve IIb) engaged less in sports and started at a much higher level of errors than either K or W. Subject H (Curve IVb) in the second group was the one who started lowest in terms of errors. He had had much experience in playing ball and in driving a car, both of which require quite accurate judgment of direction. He also reached a low level of errors early. The task seemed to be hardest for Kl (Curve Vb). He started much higher in errors than the other two and reached the same level of achievement only after long practice.

On the whole the manner in which the problem was attacked by all the subjects was essentially the same. They started out hitting the pendulum at all places sending it in all directions. The main factors in the task were to know just where to tap the pendulum and just how to place the finger so that tapping would make it go forward just to the zero mark on the direction arc. At first all subjects were interested in striking the pendulum at any place and seeing it knock down any one of the vanes on the direction arc. Gradually they began to notice that one had to hit the pendulum in a certain way and in a definite place, neither too high nor too low, in order to keep it from going in one of the two extreme directions. Still later the position of the finger was taken into consideration. Some got this idea earlier than others, but all got it before the task was learned. Some subjects, after grasping the main essentials of the problem, were satisfied, and

tried only to maintain the standard reached, while others paid more attention to details even after having grasped the general idea. Subject H grasped the main essentials quite quickly but was satisfied with that. His improvement, therefore, after the 11th practice was very slow and seemed to have reached the limit long before the others. The other subjects, after grasping the general idea, turned their attention to such details as hitting the pendulum so that it would swing smoothly and waiting until it was perfectly still before making another hit.

Analysis of the curves I–VIb shows that they have the same general shape as those obtained for timing. Progress was more rapid at the beginning of learning, especially in curves IIb and Vb. It was least in curve Ib. Curve Ib started at a lower level of errors than any other and, with practice, improvement slowed down gradually until the limit was reached.

In the case of curve IIb improvement was very rapid at the beginning, probably due to the fact that the subject was rather awkward at first and with practice improvement was more obvious. After the general idea had been grasped, the subject was pleased with her performance and eager to continue to make good scores. During the following days she maintained the same level of achievement but with a feeling of tension. After five more weeks of practice with scores improving slowly, she felt that she had the task well in hand and, being more relaxed, began to notice such details as placement of the finger to make the pendulum swing smoothly and waiting until the pendulum was entirely still before making the next hit. This refinement of detail with ease of attitude brought down the error score and accounts for the downward slope of the curve after the 20th practice until the limit was reached. Here we have a plateau appearing, due to the necessity of automatizing a skill to the point where strain could give way to relaxation and the subject could be free to give attention to refinement of detail.

Curve IIIb for subject W started a little higher than curve Ib, though not very much higher, and improvement was gradual until the limit was reached.

In curve Vb the subject (Kl) began very high in errors, was awkward at the work, and had some difficulty in getting started. He often complained that the arm got tired very quickly. After the first few practice periods he became more accustomed to the situation and improvement followed. When he reached the point where he was hitting somewhere near the zero vane, instead of at about the 6th or 7th vane toward either end, he was pleased with his own improvement and began to seek the best method of pushing and the best position for the hand. After two more weeks of practice he said aloud one day, " Now I know just when I can hit the zero. My hand has to be in a particular position and I must hit the pendulum on a particular spot. I have a definite feeling when I get zero." With this realization he took things more naturally and tried to note details, and his score improved thereafter. This improvement caused the practice periods just preceding it, 15–26, to appear as a time of slow progress or plateau. Here again is an instance in which tenseness during automatization of habit apparently caused a plateau, and special attention to refinement after a relaxed attitude had been attained brought the error score down.

In curve IVb the subject (H) got hold of the situation quickly and direction was not as difficult for him as it was for some of the others. His score on the first day was better than on the two following days. This probably was due to the fact that he thought direction was easy and at first wanted to make a good score. He improved quickly with large day to day fluctuations, but after the early general improvement progress was slow until the end of learning.

Curve VIb also shows more rapid improvement at the beginning than later. Beginning with practice number six, for a whole week the subject (Ws) showed no definite improvement aside from daily fluctuations. From his introspections it was found that tests in other school work made him lose sleep during this period and, being rather tired, he did not seem to be able to work well when he came into the laboratory. On the following days he tried to improve but could not, and was worried over the results. Here again over-anxiety or, as some authors call it,

misdirected effort, caused progress to remain at a standstill. After that week of school tests, he worked more normally and improvement came gradually. In his case again, more attention to detail near the end of learning brought the error curve down to a lower level.

Analyzing the results of this experiment, it is apparent that no long periods of non-progress were present but that there were intervals of little or no improvement. These, as has been pointed out, were due either to retardation caused by anxiety or misdirected effort, or to the necessity of getting the level of skill achieved automatized enough so that strain could be replaced by relaxation and the subject could give attention to refinement of detail near the end of the learning period.

D. EXPERIMENT 3

Force (Simple Skill)

a. *Procedure*

The task of the subject in this experiment was to swing the pendulum up the force index surface as far as the white zero line. Again he was instructed to sit comfortably at the table with his left arm in the arm rest. After the "ready" signal from the operator he was to hit the pendulum with the tip of the finger or with the thimble, as the case might be, with just the amount of force necessary to bring it exactly to the zero line. One hundred trials were given each day and after each trial the line actually reached by the pendulum before it started to swing back was reported to the subject and recorded by the operator. The subjects in this experiment were the same individuals who had served in the two preceding experiments, and the distribution of practice was the same for each. The average score made in the 100 trials was taken as the score for the day. Each subject worked at a definite hour each time and a rest was taken after the 50th trial.

The results of this experiment are presented in curves I–VIc. These curves indicate the nature of progress in the course of

learning and were plotted with the divisions on the x-axes representing practice periods and the divisions of the y-axes representing the score of the day.

b. *Discussion of Results*

This task of estimating force appears to have been the easiest of all the tasks undertaken up to this point, though it was more difficult for those subjects who had to hit the pendulum with a thimble than for those who hit it with the bare finger. Neither was there equality of performance at the beginning among members of the same group. Two persons in the group of those who did not wear the thimble and practiced three times per week started very low in errors, while another of the same group started at the highest error point of all. It was entirely a process of trial and error at the beginning. At first no subject hit the pendulum hard enough to send it even as far as the 7th line below the white zero line on the force index surface. After a few tens of trials each subject began to have some appreciation of the force exerted. Then the tendency was to use too much force and the pendulum went too far beyond the zero line. To get some general feeling of force exerted while hitting the pendulum proved to be the easiest task of all, however, and finally the point was reached where the subjects were able to approach the zero line. All of them learned the task comparatively quickly.

Curves IIc and IIIc represent the progress of subjects L and W respectively. Both of them in previous experience had acquired considerable skill in the exercise of judging small amounts of force. They seemed better able than the others to refrain from exerting too much force once they had gotten the pendulum to swing as far as the zero point. For them there was gradual improvement with continued practice until they almost reached perfection. Curve IVc belongs to subject H whose improvement was gradual from beginning to end. Curves Ic, Vc and VIc show the nature of the course of improvement of subjects K, Kl and Ws respectively. For all of them, improvement was rapid at the beginning and gradually slower until the end of learning.

In none of these curves do we find areas which seem to indicate very little or no improvement. Apparently one reason for this is that in this task all that is needed is the general feeling one gets when he employs the right amount of force, and it seems much easier to tell just when and how one has erred. In the other skills previously described there are details which could not be grasped all at once and hence, as attention was directed to the refinement of detail after a fair degree of success had been attained, the curve sloped downward near the end.

E. EXPERIMENT 4

Complex Skill, Involving Time, Direction and Force Operating Simultaneously and Independently

a. *Procedure*

In this experiment the subjects were required to master together as a complex skill the three elements previously investigated separately as simple motor skills. It was possible for them to attend either to the task as a whole or to the separate parts of the task, as each chose. The apparatus used and the position assumed by the subjects were the same as before. At the signal of "ready" the operator released the time arc and the subject tried to perform successfully the three operations in a single act—to estimate the time interval necessary in order to strike down the zero vane on the time arc, to hit the zero vane on the direction arc as the pendulum swung toward it, and to exert just enough force to swing the pendulum to the zero line on the force index surface. After each trial the marks actually hit were reported to the subject and recorded by the operator. For example, the record of a trial might read thus: time, +7; direction, −9; force, −5. One hundred trials were given to each subject during each practice period. The daily record was computed by finding the average error per trial for each of the separate elements.

The subjects were divided into two groups. One group had no previous experience with any part of the apparatus and so all

three components of the complex skill, as well as the complex skill itself, were entirely new to them. Their task was to learn to hit the three zero marks at once. The other group was composed of those individuals who had previously learned the three part processes separately, but had not thought of them as composing a single complex skill. Now they were to try to acquire the skill of hitting all three zeros at once. As this experiment was conducted during each of two school years, those who did the work in the first year, including both groups of subjects, were given three practices per week and did not wear a thimble, while the others who worked in the second year were given five practices per week on successive days and hit the pendulum with the thimble. Thus there were 11 subjects, for five of whom the task was entirely new and six of whom had previously learned the part processes involved. They practiced as follows:

Task entirely new:	Part processes previously learned:
Subjects F and M—	Subjects K, L and W—
3 practices per week	3 practices per week
Uncovered finger	Uncovered finger
Subjects Hy, Mg and T—	Subjects H, Kl and Ws—
5 practices per week	5 practices per week
Thimble on finger	Thimble on finger

The subjects for whom the task was entirely new were students in the beginning course in psychology.

In this experiment the results obtained for each subject were tabulated in the following manner. The column at the left numbered the practice periods in serial order. The three columns to the right of that gave the daily average error scores for each of the three elements—force, direction and time—determined and recorded as in the experiments already described. Then the highest error score in each element was arbitrarily assigned a value of 100% and the other scores in the same column were related to it by finding what per cent each was of that highest or 100% error. When this had been done for each item in each of the three columns, the percentage error values of the three

elements for the same practice period were added and averaged, and a fourth column was included giving these combined percentage error averages for each practice period. To illustrate, the table below gives the record of one subject (M) in his first seven trials.

TABLE I

Number of Practice	Amount of Error			
	Force	Direction	Time	Combined
1	2.48 (67.57%)	5.57 (97.89%)	3.49 (100.00%)	88.48%
2	3.43 (93.46%)	4.95 (86.99%)	2.56 (73.35%)	84.60%
3	1.10 (29.97%)	5.69 (100.00%)	2.26 (64.75%)	64.91%
4	1.40 (38.14%)	3.52 (61.86%)	2.94 (84.24%)	61.41%
5	3.67 (100.00%)	3.76 (66.08%)	3.14 (89.97%)	85.35%
6	.68 (18.55%)	3.79 (66.60%)	2.33 (66.76%)	50.64%
7	1.17 (31.85%)	2.62 (46.06%)	2.10 (60.45%)	46.12%

M's highest force error, occurring in the fifth trial, was assigned 100% and the percentage values assigned the force errors of the other six trials were computed as proportions of that highest or 100% error. In each case the percentage error value was recorded in parentheses beside the absolute error score. By the same procedure percentage values for direction and time errors were computed and recorded. Each item in the final column, being the average of the three percentage errors for the given practice period, has been taken to represent the combined percentage of error for that period.

Curves I–VI, d, e, f, and g, show the course of learning for those subjects who had mastered the simple processes separately before beginning practice of the complex skill, and curves VII–XI, a, b, c, and d, show the course of learning for the subjects to whom the learning problem was an entirely new one. In each curve the practice periods are represented on the x-axis and the scores on the y-axis. Because of vacation periods during the university year and occasional unavoidable absences for other reasons, there were necessary breaks in the series of practice periods for some subjects. The positions of such breaks and their lengths in number of days are indicated on the curves in which they occurred.

b. *Discussion of Results*

The purposes of this experiment were (a) to obtain curves for the learning of a complex skill and (b) to compare the curves obtained when the simple elements of the complex skill were known to the subjects with those obtained when the subjects were totally unacquainted with the simple elements involved.

We shall consider first the data obtained for the six subjects who had previously learned the simple processes. Because of class schedules, learning of these simple elements was not started by all of them nor in all the part processes at the same time, nor discontinued by all at the same time. This, of course, meant that the interval between the completion of learning each of the simple processes and the beginning of the complex task could not be the same for all. Some elements were learned earlier than others. In some cases the interval was very short or there was none at all, while in others it was fairly long. However, practice was continued for each process, once it had been begun, until the results indicated that the subjects had attained their limit of proficiency or, in some cases, almost perfection. The intervals between the completion of the learning of each simple process and the beginning of the complex learning were as follows:

	Force	Direction	Time
Subject K	1 week	3 weeks	6 weeks
Subject L	2 days	2 weeks	4 weeks
Subject W	1 day	1 day	4 weeks
Subject Kl	2 weeks	3 weeks	2 weeks
Subject H	2 weeks	3 weeks	2 weeks
Subject Ws	2 weeks	2 weeks	5 weeks

The two-week interval for subjects Kl, H and Ws was caused by winter vacation, while the other intervals represent instances when each had to wait until he had learned all the processes.

When these subjects started learning the complex task most of them tried to think of it as a whole complex, but consisting of three parts. Each one of them had difficulty in reaching the three goals all at the same time. They claimed that the previous learning of parts did help, but that this combined task was more difficult than any of the simple learning acts. The following abstract from the introspections of subject W written on the

first day of practice on the complex task represents the general attitude in the group: "In trying to reach the goal of timing, direction and force, I did three things at one time, that is, trying to time, watch the direction where the pendulum should go, and last of all trying to regulate my force in sending up the pendulum. The previous learning of the three separately did help me a lot, only in putting the three together I was almost as excited as when I first learned them separately. So I found it hard to get them—the time, the direction, and the force. It is much more difficult than when I learned them separately." In all cases, excepting one, force was the one part process that was least disturbed by being brought into the complex pattern. For all subjects this difficulty of reorganization was overcome after a few practices and the learning went on smoothly.

Curves Id–g show the learning of subject K. A comparison of his achievement on the last day of practice on each of the simple processes with his achievement on each of them on the first day of practice of the complex skill indicates that the most difficult item for him on this first day of complex learning was direction. The other two processes were kept at about the same degree of accuracy as at the end of simple learning. In his comments on that day he said that, although he knew he had learned the simple processes before, this complex skill was a totally strange task to him and, though he tried to regard the whole task as a complex pattern, it was difficult to get the part processes all correct. This strangeness of the new task continued for a few days, during which time the score was sometimes low in time and high in direction and sometimes the reverse. Force seemed to be no problem after the first day. Thus with fluctuation of scores in direction and time the total improvement remained more or less at a level. After the first week or so the strangeness of the task disappeared and the work progressed smoothly with quick improvement. With continued practice improvement gradually decreased. Excepting for the slow progress at the beginning, due mainly to the difficulty of having to build a new pattern out of once independent patterns, but somewhat to relearning, no plateau of long duration was evident.

Curves IId–g represent the learning of the complex skill by subject L. On the first day of practice force remained the same as on the last practice in simple learning, but in the other two processes errors were considerably higher. Aside from the first rapid fall in the curve on the second day there was again a period of difficulty, similar to that found in curve Ig. The curves for the separate part processes indicate that the subject had more difficulty with direction on the first few days than with the other processes. It is interesting to note in her introspections on those days that she said she was holding her finger in a special position for direction and went on trying to strike the three zeros at once. On the 5th practice the error scores for time and direction were reversed, direction being low and time high. Force fluctuated a little from day to day. Thus the total result for those first five days was no progress in the whole task. The shifting of scores from day to day indicated that the factor causing most difficulty was rebuilding the pattern. Practice periods 10–14 show another interval of no improvement. This may be explained by the fact that those periods came during the week of final examinations in the university. After the examination period, improvement progressed rapidly for two or three days and then slowed down to approach the limit. In the case of this subject again, the task was performed smoothly as a whole after the difficulty of rebuilding pattern was overcome.

Subject W, whose learning is represented by curves IIId–g, also found much difficulty in beginning the complex task, although she had finished the work on direction and force just the day before. As her introspections indicate, she was as disturbed at the beginning of this complex process as when she first started the simple ones. Her scores on the first day of complex learning show that her proficiency in direction and time was less than at the end of practice on those part processes. As with the other two subjects, force was the first element brought under control. She tried to regard the task as a whole from the first and her results for separate processes show that when one score was low the other followed in the same direction. After the first

five days of difficulty in coördination improvement came quickly and soon reached a level. This held until the last two days, after she had left behind her all the burdens of the school year and was planning to go away, when her error score came down again in a last effort to do her best. The sudden fall in timing error on the 7th day of practice, which also brought down the total curve, was due to the fact that she was not as tired as she had been on the preceding days and disturbing noises from outside did not affect her as much. It is evident that time was comparatively more difficult for this subject in the complex learning. This may be explained in several ways. One possible reason is that time being the one process requiring most concentration of attention, disturbance affected it most. Hence, when she had to combine the simple processes, time was the one most disturbed. Another reason might have been that, for her, time was the one element for which there was an interval before beginning practice on the complex skill and some relearning had to take place. The fact that her introspections on the 6th day, relating that she was less tired, better able to concentrate and less disturbed by outside noises, coincided with a sudden fall in timing errors, indicates that the first reason suggested is probably the main one. Hence in the case of subject W, although she was able to regard the task as a whole, the fact of having to consider the three processes all at once caused difficulty and resulted in very slow or almost no progress for the first few days.

Subject Kl (Curves V, d–g) regarded the three processes as separate at first when he was required to master them together. His practice on the complex skill began immediately after a winter vacation, making an interval of two weeks between the completion of the simple learning and the beginning of the complex learning. Comparison of his achievement at the end of each simple learning process and his record for the separate parts on the first day of complex learning shows that there was considerable loss in all the part processes. This may have been due to the effect of vacation or to difficulty in rebuilding a new pattern out of old ones. When he first started the work he said in his introspections that it was impossible to combine all the three

separate elements into one process; that when he tried to better his timing, direction would go off; and when he tried to improve direction, timing went awry. His difficulty in rebuilding pattern at the start is most clearly indicated by the fact that even force, which was easy for other subjects, fell off considerably for him. It seemed different to have to judge force when one was trying to judge something else at the same time. Direction and force improved very quickly on the second day, giving a rapid fall in the total curve for the second practice. After the second day force became fairly accurate and attention was divided between time and direction. By constant shifting of attention from one to the other part process on the same day the subject was able to to improve in all processes during this practice period and improvement continued thereafter with further practice. This is different from what took place in learning by the other subjects whose work has been described and who tried to regard the task as a complex whole from the start. Kl progressed rapidly and continuously until the 12th practice when the task seemed just to fuse into one whole for him. It is to be noted that from that time on progress became slower until a limit seems to have been reached. There was no plateau of long duration in his curve (Vg) for learning the complex skill. There was no interval of slow progress in his curves at the beginning of learning, such as are found in the curves previously discussed, probably because he consciously attended to a process whenever he realized he was not doing well with it and thus improved in it. In this way he was able to achieve some progress in each of the simple processes during each practice period and so to make improvement in his total curve. This was borne out both by the objective results and by his introspections.

Curve IVg shows the nature of improvement for subject H in learning the complex task. Comparison of his results on the last day of practice of each simple process with his results on separate parts (Curves IV, d, e, f) on the first day of the complex act shows that force continued the same while direction and time were very much less accurate. Time, for which the interval had been shorter than for direction, showed a greater loss of pro-

ficiency. As was true for all the other subjects, the first day for H was difficult, so the curve of errors started rather high, but fell off considerably the next day. The improvement from the second to the sixth days was rather slow and irregular. From his introspections, it is clear that when he started the work he endeavored to treat the task as a complex whole, not paying more attention to any one component process than to another. He soon realized that time was more difficult for him than the other elements, but continued to try to attend to all three equally at once. This effort resulted in slow progress or even loss of progress in time, with improvement in direction. This fact is mostly clearly indicated in the separate part curves where time either stands at a level or goes up. In the total curve (IVg) progress appeared slow. After the 5th practice he decided that, since time was most difficult for him, he would give a little more attention to it than to the other elements. With this the curve of errors fell. From this point on, he tried to regard the task as a complex whole again as much as possible, paying only a little more attention to time, and daily improvement resulted. The sudden improvement in the total curve after the 5th practice is apparently due to more than usual improvement in timing. The increase in errors during the 11th practice was due to the physical condition of the subject, as he had lost much sleep during the two preceding nights, was feeling drowsy, and was unable to concentrate on the work. Evidently for him the slow progress at the beginning was due largely to the difficulty of having to coördinate the formerly independent processes into a complex pattern for, if relearning or forgetting had been the main factor, he should have had more difficulty with direction which had the longer interval of non-practice before complex learning was begun.

The learning of subject Ws was somewhat complicated by his unfavorable physical condition during the first two weeks. When instructed to learn the complex task combining the three elements already learned, he found it difficult to regard them as a whole rather than as separate parts. Curves VId–g represent his learning. Comparison of the scores on the last practice in each of the separate tasks with the results of each separate process on

the first day of complex learning shows that all three increased in error and that direction for which the interval was much shorter than for time, suffered the most loss. As is true for other subjects, Ws started rather high in errors on the first day and came down quickly on the second day. This probably was due to getting more accustomed to the whole situation after the first day of practice. From the start, force was found to be least difficult and direction most difficult to bring into the coördination. Therefore he concentrated most on direction and next most on time, giving very little attention to force. A study of the separate curves (VId, e, f) shows that improvement was taking place in each of the elements, though not as fast as it had for some other subjects, especially for Kl. This perhaps may be explained by the fact that his error score was not very high after the first day of practice on the new combination. Another factor, which undoubtedly entered into his results of the first two weeks, was the fact that he had a severe cold during all that time. One day when he was feeling better (the seventh) his error score went down. On the whole, for almost three weeks it was difficult for him to get time and direction to the point where he did not need to think of them separately. Beginning with the end of the third week they seemed to fall together more easily and work became more or less automatic. The upturn in the curve in the 20th practice was caused by a break during the final examination period. After a few days of relearning, progress continued until the limit was reached. In this case again, at the very beginning building a new pattern out of formerly independent ones and an unfavorable physical condition caused slow progress, though not non-progress.

A general review of the data for all subjects who undertook the complex learning after having already learned separately the elements involved, shows that the final error score obtained for the separate factors at the end of complex learning was lower than the final score at the end of simple learning of force, but about equal for direction and time. There were some points of difference among subjects in the latter two, but they were not great. A more important fact which stands out is that the task

was not merely one of combining the simple processes, but that there was pattern involved. When the simple processes were being learned, each of them formed one pattern; when they were put together, there was a pattern of the whole which was difficult to grasp at the beginning, due to the fact that the simple patterns had previously been regarded as wholes in themselves. Reorganization was necessary before the learner could regard them as constituting a single whole together, and it was this difficulty of rebuilding pattern which caused periods of slow progress in some of the learning. This was especially true when subjects made an effort to regard the whole as a whole from the beginning. For those subjects who, after finding which proved to be the most difficult part process in the coördination, attended to it specifically, there was less delay in improvement in total learning. After the difficulty of reorganizing the once independent simple patterns was overcome, real learning of the complex pattern was under way, and the curves show that there were no plateaus. This was to be expected, for now all simple elements were familiar in the new relationship and there was no need of giving special attention to any of them.

It has been stated above that five of the eleven subjects who took part in this experiment were totally unacquainted with the task and the apparatus. It was pointed out also that the task was of such a nature that a subject during learning might attend either to one part process at a time or to the whole. The form of the learning curve should vary according to the method adopted by the learner. If, according to Batson, plateaus are produced by attention to different parts at different times during the course of learning, then those subjects who attended to the whole complex task from the beginning to the end should not have any plateaus of long duration in their curves, while those who did attend to a part at a time should show plateaus in their curves of learning. Let us now turn to the curves for these subjects individually.

Subject F, whose learning is represented by Curves VIIa–d, had no previous acquaintance with any part of the task. He had all at once to try to estimate time, to push the pendulum in the

right direction, and to use just enough force so that it would go neither higher nor lower than the white zero line on the force index surface. At first he found it a problem to hit anything at all on the time and direction arcs and to get enough force in the stroke to make the pendulum go any reasonable distance. The subject was pleased when he could hit even a + or −9 on the time arc, any unit on the direction arc, and get the pendulum to go even as far as the line numbered −7. The counting method was used for estimating time. Direction depended upon hitting the pendulum at a certain place and holding the hand and finger in a certain position. He had to try again and again in order to find the amount of force that would take the pendulum just to the zero line. Attempts in all three were made repeatedly until he was able to get all somewhere in the vicinity of zero. Generally improvement was more rapid when he was working away from the two extremes toward the center section but, after reaching the central area, finer judgment was needed and improvement became slower. With continued practice the point was finally reached where he was able, not only to hit the three zero points together, but also to do it more or less automatically so that little attention was required in the performance. A study of his curves shows no plateau whatsoever anywhere in the curve of total learning (VIId). Analysis of the curves for each of the component processes (VII a–c) also indicates that progress took place in all the parts at the same time until the skill was learned. Introspections, too, point to the fact that from the first he regarded the whole task as a single complex. The rapid fall at the beginning of the curve was probably due to getting acquainted with the apparatus and with the entire situation involved in the experiment. On the whole, it can be said that his curve shows rapid progress at the beginning and, with continued practice, gradually slower progress until the end of learning. There is no plateau in this curve. It should be noted that a delay of two weeks between practices 32 and 33 caused no loss.

Subject M, like subject F, practiced three times a week on the skill for forty hours and his learning progress is represented in Curves VIIIa–d. He, too, resorted to trial and error for his

first successes and his general procedure was about the same as that of subject F. Although he started very high in errors, he was able to improve more rapidly, reaching a lower level of error earlier than did subject F. This shows a difference in individuals in their speed of learning the skill which in this instance may be accounted for by previous experience, for subject M was an athlete. His curve also exhibits no plateau, but rapid progress at the beginning and then more gradual improvement, showing negative acceleration with continued practice. Analysis of the curves shows that improvement was taking place in all the part processes at the same time, resulting in continuous improvement in the total curve. Introspections written at the time of learning likewise indicate that the subject regarded the task as a complex whole from the very beginning and continued to regard it so until the end of learning. Again no backset resulted from the interval of two weeks between practices 31 and 32.

Subject Hy practiced five times a week and hit the pendulum with a thimble. This subject also was interested in sports. Besides, he played the violin and said that he had never experienced much difficulty in using his hands. Obviously he had considerable experience in activities which required manual skill and judgment of time. In this experiment he seemed awkward and uncomfortable in the task at first as was true of the other subjects. By trial and error he learned to keep away from extreme errors. Instead of employing the method of counting for time he tried to make a mental estimate of the interval needed. He regarded the task as a whole and endeavored to attend to all parts at once. At first he found it very tiresome; his muscles became stiff and his arm ached; but with continued practice this strain disappeared and the task became easier. Gradually his performance improved. In comparison with other subjects, he approached the central area relatively more quickly in all three elements, but the refinement of reaching exact zero came much more slowly. His curves (IXa–d) show that on the whole improvement took place in all parts at the same time and that there is no period of retarded progress due to specific attention to any one part. This curve is similar to those of the other sub-

jects already discussed. There was rapid progress at the beginning and slower progress as learning approached the limit. No loss resulted from a delay of two weeks between practices 46 and 47.

Curves XIa–d give the nature of the improvement of learning for subject T. This subject had much experience in activities which required accuracy and precision. He played the piano and violin, and was more used to laboratory situations than most of the other subjects. At first he was awkward, as were the others, but he seemed to be able to get adjusted to the situation more quickly than they. From the start he kept calm and tried to find the best method of reaching his goal. It was again a trial and error process. He did not count, but tried to estimate time mentally. Direction, he soon discovered, depended upon where and how he hit the pendulum, and force need not be very great in order to send the pendulum to zero. Improvement was quick in going from extremely high error scores to somewhere near zero, but further progress was much slower. Gradually with continuation of practice, the subject was able to hit all three zeros at the same time and felt at ease in the problem. The curve shows rapid progress at the beginning and continually slower progress thereafter until a level was reached. There was no plateau in the total curve of learning. Analysis of the curves shows that he was improving in all of the part processes at the same time and his introspections indicate that he regarded the task as a whole from the start. The elevation in the curve (XId) at practice periods 23–25 was due to the physical and mental condition of the subject. This was a time when tests were being given in other school work and he was tired when he came to the laboratory. Possibly the 17-day vacational break caused the slight elevation in the curve after the 46th practice period, but this rise was due entirely to time error and disappeared within a few days. On the whole, then, we may say that the subject regarded the task as a complex whole from the start and there was no arrest of progress in his curve of learning.

Subject Mg (Curves Xa–d) was an individual little experienced in fine muscular control of arm and hand. The whole

laboratory situation was new to him and he was awkward at first. Although he had been instructed that his task was to reach the three zeros at the same time, he apparently decided after the first day of random hit and miss to try to learn one part process at a time. This was very evident in his curves for component processes, and his introspections verified the assumption. Attention was first centered entirely on timing. Counting was used to get an idea of the time necessary. After the first ten practices, time was accepted as having reached some degree of proficiency and attention was turned to force. Direction was taken into account after time and force had reached a point where they did not require special attention and then, with attention directed upon the least improved element (direction), progress followed in all three and there was a rapid fall in the total error curve thereafter. Hence we have a period of slow progress at the beginning caused by attention to time alone with no improvement in the other two, then a second period of slow improvement in the total curve caused by attending to force (though not yet to direction) with additional improvement in time due to practice. When vacation started, although he had had as many practice periods as subjects Hy and T, this subject had not yet reached the point of proficiency that had been attained by them. A vacational break had more effect on his results than on the results of the other subjects. This undoubtedly is due to the fact that his skill was not so well established and interruption weakened it more. After two weeks of further practice he was able, not only to regain the old level of achievement, but to reach a point even lower in error than in the prevacation period. In his case we have facts which indicate that plateaus, or periods of very slow progress in the complex act, may be caused by centering attention on special elements of the task rather than on the total process. The other four subjects, who had regarded the task as a single complex act, did not have any plateaus in their learning curves, while this one, who chose to attend to the part processes separately, did have two distinct periods during which there was almost no progress at all.

Comparing curves for the subjects of both groups—those who had and those who had not learned the part processes separately before beginning the complex task—we find that the members of the former group started at a very much lower level of error than those of the latter group. The former subjects, however, did find it difficult at first to rebuild the simple patterns into one unitary whole. It would have been desirable to retest them in each of the single elements before permitting them to begin the complex learning; but forgetting seems to have been a minor item since, for the subjects of the other group, its effect proved to be negligible with similar gaps between practices. Whenever for a subject of the former group, the difficulty of combination had been overcome and special attention did not have to be given any one element, the learning curve sloped smoothly and rapidly downward for a few periods and then gradually more slowly downward. The general form of the curve, after combining difficulties had been overcome, was the same as the latter portion of the curve for a subject of the latter group who regarded his task as a complex whole. In either case there was no plateau. It was different, however, from the curve obtained when, in learning the complex skill as a new problem, attention was directed to different part processes at different times.

IV. TYPE II—EXPERIMENTS

COMPLEX MOTOR SKILL, INVOLVING COMPONENT PARTS OPERATING IN SUCCESSION AND ONE DEPENDENT UPON THE OTHERS

A. DESCRIPTION OF APPARATUS

The experiments of type II included tasks of simple and complex learning, as did those of the first type, but differed from those of the first type in that the simple parts of the complex learning were so related to one another that the functioning of the second depended upon success in the first. Furthermore, the elements in the complex task of the second type operated in succession, while those in the first task had operated simultaneously. There were three experiments in this group, two for simple learning and one for complex learning. Here again one apparatus and its parts served for learning the task, either as a whole or in parts. The simple tasks which the subject learned separately formed the elements of the complex task. The apparatus used in these experiments is described below.

Figure II gives a general sketch of the apparatus.

(D) is a disc, 26 inches in diameter and 1¾ inches in thickness, which is fastened to a table through an axis held by a clamp. Four small holes ⅜ of an inch in diameter were dented on the surface of the disc, ⅞ of an inch from the circumference and at irregular intervals. Over each of these dented holes a card of white paper, 6¼ by 1⅜ inches with a ⅜ inch hole in it, was placed so that the hole in the card coincided with the dent on the disc. This hole was nearer to one end of the card than to the other and nearer to one edge than to the other. There was a distance of $3\,{}^{11}/_{16}$ inches from the long end of the card to the hole and of 2⅝ inches from the short end of the card to the hole, and a distance of ${}^{25}/_{32}$ of an inch from one edge and ${}^{27}/_{32}$ of an inch from the other edge to the center of the hole. These cards

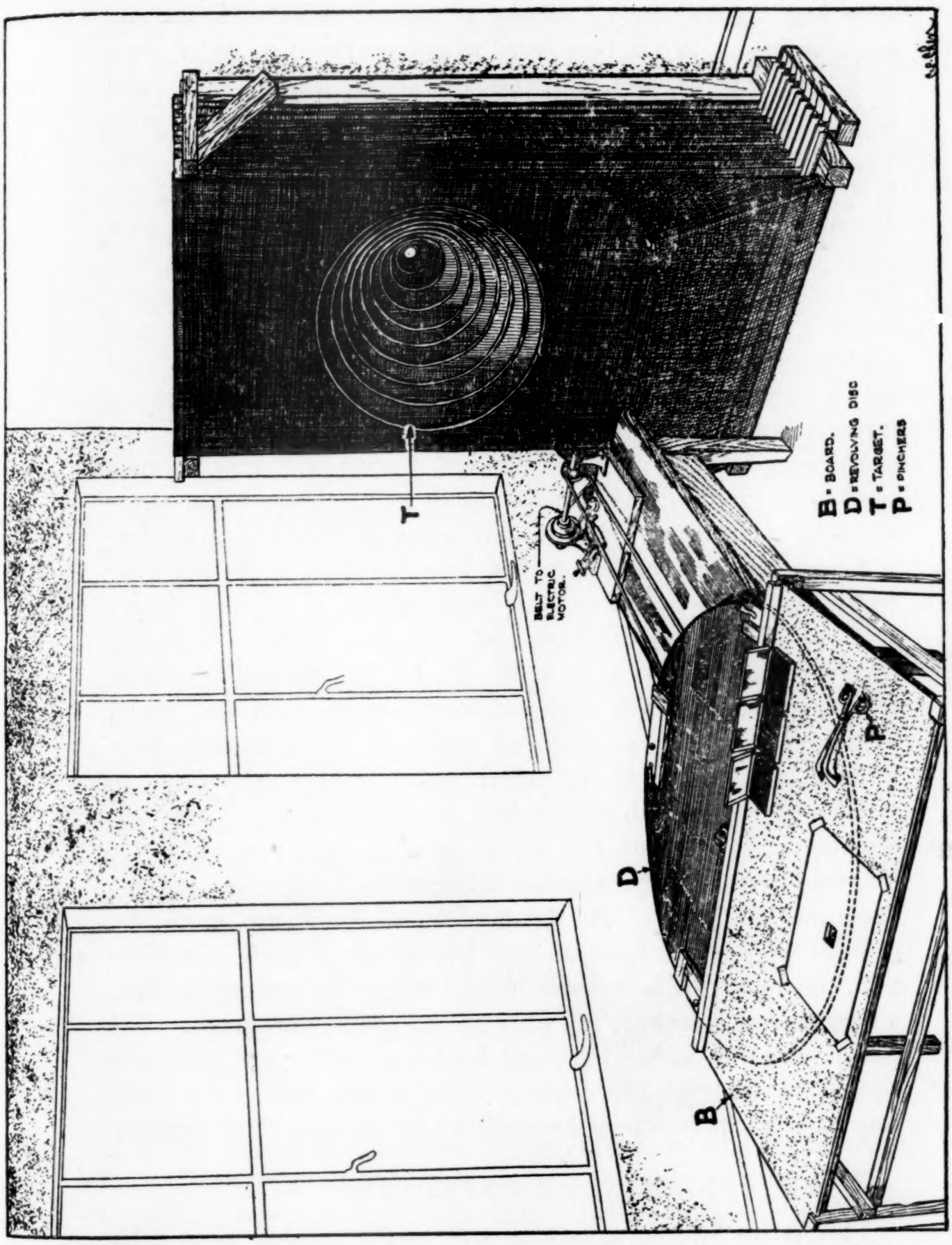
B - BOARD.
D = REVOLVING DISC
T = TARGET.
P = PINCHERS
T
BELT TO ELECTRIC MOTOR.
P
D
B

FIGURE II

were kept in position by means of narrow wooden strips and brass springs. When they were placed on the disc, there were four irregular chordal intervals of 17⅛, 16½, 17 5/16 and 17 9/16 inches, respectively, between each two successive cards, and the spaces between them were painted black. A small lead shot was placed in each of the holes of the cards making the disc appear as a table 39½ inches above the floor, carrying four white cards each with a lead shot near one end. The disc was attached to a motor at the opposite end of the table with proper reducing gears. Three-eighths of an inch above the disc and covering one-half of it was a board of "Prestwood" (B), 39 by 14 inches and 5/32 of an inch thick, with a square hole cut through it at 2⅝ inches from the edge nearest the subject. This board was held in place by wooden frames and was in such relation to the disc that the black shots on the white paper cards appeared at the center of the square when the disc was in motion.

Ninety-six and one-half inches from the hole in the covering board and perpendicular to it was placed a wooden target frame (T) 78½ inches high and 34 inches wide. Concentric rings of diameters 2, 4, 6, 8, 10, 12, 14, 16, 20, and 24 inches were cut out from side strips of black percale cloth and bound with steel wire. These strips of cloth with the concentric rings in them were nailed to the target frame at top and bottom in serial progression with the smallest one at the back. There was a distance or depth of 1⅜ inches between each two successive concentric rings. The distance between the 2-inch ring and the floor was 44 inches. At the bottom of the frame work, tin troughs were placed between each two strips of cloth. In addition, the apparatus included a pair of tongs for picking up shot, a metronome, and three ink pads of red, black, and green. The tongs were 4½ inches long and bent, one inch from the lower end, at an angle of 120 degrees. The seizing end of the tongs was ¼ of an inch wide and roughened on the two inner surfaces.

B. PRELIMINARY EXPERIMENTATION

This set-up of the apparatus was finally decided upon after a year of preliminary experimentation. In the preliminary study

the apparatus used was essentially the same as this excepting that the target frame was set a few feet farther away from the disc, a heavier pair of tongs with a longer lever was used, the hole in the board covering part of the disc was one inch round instead of square, and the disc rotated at a speed of six revolutions per minute instead of three and one-half. Under the conditions of the preliminary experiment the learning proved to be so difficult that no subject could reach an acceptable degree of success within a reasonable period of time. It was necessary, therefore, to change the apparatus so that the skill could be acquired.

A detailed description of this investigation and a record of the results obtained are contained in a manuscript copy which has been placed in the General Library of the University of Michigan. The writer has not included a report of the study in this monograph, but does desire to point out that, although the skill was not mastered by the subjects, in the progress which was made one trend was definitely apparent. When subjects attended to part processes separately there was clear evidence of plateaus in the learning curves. Learners were able to acquire timing but could not learn to pick up the shots because the tongs were too unwieldy. Nevertheless they did make enough improvement in throwing to indicate the presence of plateaus, though this, of course, was obscured by failure to learn to pick. The trend, it will be interesting to note, was in the same direction as was found in the experiments about to be described in which the improved apparatus was used.

C. EXPERIMENT 5

TIMING (SIMPLE SKILL)

a. *Procedure*

In this experiment the task of the subject was to acquire the skill of hitting into a hole at the right moment or, in other words, to learn to estimate time. The parts of the apparatus used were the white cards with holes in them, the pair of tongs, the three colored ink pads, the large wooden disc, and the Prestwood cover-

ing board. The procedure was as follows: Four cards were placed on the large disc, one over each dent in the disc. To the subject, as he stood in front of the disc, it seemed as if he were seeing black holes in white cards which passed under a square hole in the covering board. The disc was rotated by a motor at a speed of three and one-half revolutions per minute. It moved clockwise, exposing the long end of the white card first, as the card passed under the covering board. Standing in front of this covering board with the pair of tongs in his hand, the subject watched for the appearance of the white card. He estimated the time between the appearance of the edge of the long end of the card and that of the hole in the card, and tried to aim at the hole at just the right instant. In order to have a record of the exact place which the subject struck, there was applied to the seizing end of the tongs colored ink which left marks on the card whenever the subject failed to strike the hole. Red ink was used first. After reacting to the first card, the subject waited until the second one came into view and then reacted to it. This was continued until he had reacted to all four cards, after which the operator stopped the disc and adjusted the cards while the subject cleaned the tongs with water and cloth and applied black ink to them. Then the disc was set rotating again and, at the signal of "ready", the subject tried to hit the four holes as before, leaving black marks on the card whenever the hole was missed. Again the operator adjusted the cards and the subject changed the color of ink on the tongs to green. Then he tried once more to hit the four holes while the disc was running. Thus twelve attempts were made on the four cards, leaving colored marks on each card whenever the hole was missed. At the end of twelve trials, the cards were taken off and another set placed on the disc, while the subject rested. Another twelve trials were made by the subject, after which he rested while the third set of cards was placed on the running disc. This was continued until the subject had 100 trials. At the end of the day's practice the subject wrote out whatever introspections he had to offer. The distance in millimeters between each ink mark and the center of the hole in the card was taken as the measure of error for that

trial. The arithmetical average for the 100 trials was computed and constituted the score for the day's work. Each subject was given 100 trials per day at the same hour of the day and five days per week until it was apparent that he had reached his ultimate level of accomplishment. Three subjects took part in this experiment—B, N and Q—all of whom were students in the course in General Psychology. The nature of the progress made in this simple learning is shown in curves XII–XIVa, in which practice periods are represented on the x-axes and error scores on the y-axes.

b. *Discussion of Results*

All three learners began with random efforts and from the first there were differences in their success in this guessing of time intervals. Having seen the card as it lay on the disc before the disc was rotated, the subject was able to get some idea of the length of paper which should come into view before the hole would appear. Apparently some took more notice of this than others. Also subjects differed in their previous experience with reference to timing. Subject B had so much experience in timing before the experiment was begun that he knew how many numbers to count in order to cover the duration of one or two seconds. Subjects B and N both decided early to try to find the right time as nearly as possible so, after a few trials of pure guessing at wide distances, they learned to estimate closely enough to make the first day's record fairly low in terms of errors. They took the work as a real task from the start, and paid close attention to it. The third subject (Q) was also much interested in the work but treated it more as pure guess work. He tried all kinds of intervals for hitting and finally did get some general idea of how long a time the paper should be in view before the hole could be expected to appear.

Curve XIIa shows the results of the learning of subject B. He decided to get as accurate a timing as possible at the very start. The manner in which he tried to find the correct time to strike is best described by his own introspections written after the first day's work, dated October 10th. "At first I was inter-

ested in timing the speed of the wheel and the time between the pieces of paper. Having that in my mind, I tried to measure the time that elapsed from the time when the first corner of the paper came into view until the hole appeared. Finding that this was about ½ second, I then relaxed while the level wood was in view, started concentrating when the raised wood appeared, counted half a second from the first view of the paper, and then shoved the tongs down in the center of the square." As observed by the operator, a certain number was counted in each trial as he tried to estimate the time. This method of timing was used by this subject for some weeks until the task became easy and more or less automatic, when he gave up counting for the most part, though he still reverted to it occasionally. This subject, therefore, tried to think out a method of determining time interval before starting the work and, after deciding on the approximate time needed, stuck to it as a guide. Improvement came with continued practice. His curve shows that after the rapid drop on the first two days, which probably was due to getting acquainted with the whole situation, his improvement came gradually with negative acceleration until the end. The rise on the 27th day was due to irregularities in the motor. There were daily fluctuations, as was to be expected, but there was no period which one can call a period of non-progress or plateau.

Subject N was another who from the start tried to calculate the time he should wait before hitting at the hole. He did not use a counting method, but merely tried mentally to estimate time. He was a steady individual who tried his best. In general, his curve (XIIIa) shows rapid improvement at the beginning, then gradual slowing down with continued practice. Periods 15–22 exhibit a time of little improvement followed by a decrease in errors. There was no apparent reason for this excepting that at this time the learner had already achieved considerable improvement and was satisfied with his score. It was near the limit which he finally reached and automatization was probably taking place. Also examinations were being given in other school work and that may have been a factor in slowing down his improve-

ment. The period represented by the fall in the curve came after examinations were over and after automatization with its consequent relaxed attitude had been attained, and the subject was probably giving close attention to refinement of detail.

Subject Q took up the task as if it were another sport to be learned and in learning tried to bring in as much as he could of the methods and tricks acquired in sports. During the first few days he tried different systems of work. He tried to swing the tongs in hitting the holes as he would swing a club in playing golf. No special system of estimating time was used at the beginning. He watched for the appearance of the card, then waited until he thought it had gone far enough, and then hit. Soon the noise of hitting the hole developed into a cycle of four sounds with what seemed to him equal intervals between them. This resulted in missing the holes most of the time, although not very far; for, as will be recalled, the cards were purposely spaced at unequal distances on the running disc in order to avoid rhythm. On the third day, he was still trying to find a system for estimating time, for he realized that depending on regularity of sounds did not result in accuracy. Toward the end of practice on the third day, he decided to use a counting system. He counted as fast as he could and hit at a certain number. This counting was finally adopted as a guide. With continued practice, he habituated himself to the situation, so that the motion of the hand in hitting and the strength of hitting were gradually diminished. Confidence came with success and attention was turned to other details, such as standing in a comfortable position, swinging the tongs easily, and grasping the tongs with the maximum of skill and control. Progress with continued practice gradually made the task seem easy and counting was given up, for he was able to get an appreciation of the time interval and seemed to have an idea of the proper reaction to the whole situation. Toward the end of practice, the process became so automatic that he did not have to concentrate much, but instead watched for the appearance of the white card and, after an interval, his hand just hit. The curve of his learning (XIVa) shows very rapid progress for

a number of days at the beginning of practice. This undoubtedly was due to getting acquainted with the situation and also to the exploratory attitude taken in trying out several methods. After the first seven days of practice, progress was slower, though still fairly rapid, until one day when he was rather tired, the results were poor. He reported that it was hard for him to concentrate because of lack of sleep. This regression in the work continued for three days during which there was loss of interest produced by continued poor results and anxiety. With the recovery of good physical condition and with more sleep, his results improved again, and introspections on the 15th day show that he was trying to regain his confidence and refine the details of his response. Improvement continued for a while until a point was reached where he felt the response had become automatic and the results for more than two weeks thereafter remained at a level. He was missing very few of the holes. After automatization, which resulted in a relaxed attitude, another effort was made to improve his work near the end of learning by being more careful, and the curve came down a little more.

A review of the curves of these subjects on learning to time shows that:

1. All the curves have the general characteristic of a rapid fall at the beginning followed by more gradual improvement. This rapid fall continued longer when the scores started high in errors due to exploratory attitude or attitude of indifference than when the error score started low, probably because in the latter instance the subject began the work by adopting a specific method.

2. In two of the curves, there was a period of apparent level in the course of learning just preceding the last drop at the end. This is to be explained by the fact that more attention was given to refinement near the end after the process of automatization had been achieved, with resulting relaxation from tense feeling.

3. There is no long period of plateau found in any of these curves, although there are the two short apparent levels described above caused by refinement after automatization near the end of practice.

D. EXPERIMENT 6

THROWING (SIMPLE SKILL)

a. *Procedure*

The skill to be acquired in this experiment was that of throwing into a target a shot picked up from the board. The parts of the apparatus used were the target with its concentric rings, the Prestwood covering board, a pair of tongs, lead shots and a metronome. The subject stood in front of the board in a position which permitted free swing of the right arm toward the target. He was given twelve shots which he spread out on the board. At a "ready" signal he picked up a shot and threw it at the smallest target ring he could. The speed of throws was regulated by a metronome set at 84 beats per minute. The subject would pick up a shot and hold it in position above the square hole on the first beat, start to throw on the second beat, and have his hand back over the hole again on the fourth beat. This rate was adopted because it provided time enough to aim comfortably for throwing and yet was a little less than the time intervening between the coming into view of those two cards which would appear nearest to each other on the rotating disc. Every time a shot entered a hole it fell into a tin trough below. Twelve shots were thrown in succession after which the subject rested while the operator picked up the shots from the troughs and made a record of the number which fell into each trough and of any which fell entirely outside the target frame. This procedure was continued until the subject had thrown 100 shots.

The score for a given day was obtained in the following way. Each hole in the target was assigned a value. From the sizes of the concentric rings it is clear that the difference between the radii of the 2-inch and 4-inch rings is 1 inch, and that the two holes have 1 inch of radius in common. Therefore, if a shot were to enter the 2-inch hole it had to be within 1 inch of the center, hence the 2-inch hole was assigned the value of .5 (average of 0 and 1). Similarly, the difference between the radii of the 4- and 6-inch rings is 1 inch and they have 2 inches of radius in common. For a shot to fall into the 4-inch ring

and not into either the 2-inch or the 6-inch ring, it had to go between 1 and 2 inches from the center. Therefore the 4-inch hole was assigned the value 1.5 (average of 1 and 2). By this mode of computation the holes of diameters 6, 8, 10, 12, 14, 16, 20, and 24 inches were assigned the values 2.5, 3.5, 4.5, 5.5, 6.5, 7.5, 9, and 11 respectively. Any shot which fell outside even the 24-inch ring was treated arbitrarily as if it had entered a ring of 34 inches in diameter and assigned the value 14.5. To obtain the record of throwing for the day, the experimenter first counted the number of shots which had fallen into each hole, next calculated what per cent the number falling into each hole separately was of the total number thrown, then multiplied those percentages by the values assigned the respective holes, and added the products obtained through that multiplication. This sum, taken as the value of throw errors for the day, was reduced 100 times for convenience in tabulating data and plotting curves. Someone might suggest that the holes should have been evaluated on the basis of their proportional areas rather than on the basis of radii. Calculation shows that the values obtained by using areas of the concentric rings are (after division by the constant 2π) the same as those here adopted, with the exception of the three highest ones.[2] As very few shots fell into the large holes after learning was begun, this discrepancy with respect to those three values would have made little difference, excepting that in the beginning the fall in the learning curve would have appeared more rapid. The real measure of error, however, is the radius. Estimation by area does not take into account where the area is.

The subjects in this experiment were the same individuals who had acted as subjects in Experiment 5. Each one practiced at the same hour each day, five days per week, 100 trials per day.

The nature of progress in the course of this learning is shown in curves XII–XIVb in which the divisions on the x-axes represent practice periods and the divisions on the y-axes represent throwing scores.

[2] Since $\frac{(r+1)^2-r^2}{2}-\frac{r^2-(r-1)^2}{2}=1.$

b. *Discussion of Results*

All of the subjects who took part in this experiment (B, N, and Q) had some previous experience in shooting and throwing, but the particular set-up of this learning situation was new to them. At first they were very awkward and had to exert considerable force to send the shot even as far as the largest and nearest ring in the target frame. No one of them at first aimed at any particular ring; they tried only to make the shot reach the target. Gradually with continued practice, the shot went farther

TABLE II

Subject	Practice Periods	Values assigned Target Rings: .5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	9	11	14.5	Total	Throw Error Value
		Diameters of Target Rings: 2	4	6	8	10	12	14	16	20	24	34		
B	1–12	5.0	12.7	13.5	17.0	11.7	7.8	5.9	6.0	5.9	5.2	9.3	100	5.44
	13–24	4.9	11.3	14.3	13.8	10.1	8.0	4.9	4.6	11.3	9.0	7.8	100	5.71
	25–36	5.1	13.3	14.7	16.7	12.5	8.7	5.3	6.1	10.3	3.9	3.4	100	4.89
N	1–10	3.3	7.0	11.6	13.8	14.6	15.6	13.9	7.1	6.0	2.7	4.4	100	5.31
	11–19	4.8	14.9	14.7	21.7	15.2	10.5	7.1	3.8	4.4	1.7	1.2	100	4.26
	20–29	4.4	17.5	20.7	21.3	16.5	10.1	4.3	2.8	2.0	0.2	0.2	100	3.59
Q	1–9	2.4	6.0	11.0	13.2	12.4	12.2	9.6	9.1	7.0	4.3	12.8	100	6.33
	10–18	4.7	14.3	15.7	18.6	13.0	7.0	6.5	8.3	7.5	2.9	1.5	100	4.44
	19–27	8.0	15.6	18.4	24.2	12.4	8.6	4.3	3.9	3.9	0.6	0.1	100	3.61

and farther into the target until a limit was reached for each subject. From awkward movement at the beginning, the act became easy and natural by the time the smallest possible hole for the particular subject had been attained.

Table II, in which the total number of practice periods for each subject is divided into thirds and average results for each third of his practices are recorded (expressed in percentages), gives in condensed form the amount of progress made by each subject during the beginning, middle and last portions of the total learning process. Reference to this table will show the reader both the average values obtained with reference to the throws into each of the concentric rings and also the total average throw error value for each third of the trials taken for learning.

Curve XIIb represents the learning of subject B. His success was better on the first day than for a number of days following. He had quite a bit of experience in shooting and throwing and did not feel very awkward in starting the experiment. He stood in a comfortable position, the same position he had taken for timing. As the target frame was set at a definite height in relation to the whole apparatus, each subject had to adjust himself according to whatever was the best position for him. On the first day B threw with his body bent slightly forward and was comfortable and successful. That posture was assumed unconsciously and was lost again soon. The four following days he tried different methods of throwing until one day he decided to throw with his arm straightened out and with an upright posture. With continued practice he was able to get the act of throwing more natural and smooth but, as his curve shows, there actually was no improvement from the 5th to the 18th practices apart from minor daily fluctuations. After almost a month of practice he remarked that he felt he had been pretty successful in throwing but wanted to see if he could not improve further. It was noted by the experimenter on that day that he made an effort to bend forward a little and the results showed improvement over previous records. He retained this new posture thereafter and improvement came gradually with practice until he seemed to have reached a point where he could do no better. By this time the act had become natural and smooth and learning was completed. In this curve we have an illustration of how an early chance adoption of a queer and inefficient method of throwing seems to have prevented improvement until a better method was employed, and so caused a plateau.

Subject N, whose learning is represented in curve XIIIb, hit upon a comfortable swing of the arm and degree of bending of the upper part of the body after a few trials on the first day and continued so until the end of learning. His practice showed an initial spurt and, although improvement on the first few days was relatively more rapid than afterwards, the curve on the whole

went down gradually until he had reached a level which he seemed unable to exceed. As was true with other subjects, the action was awkward at first, but practice made it gradually more natural and easy. Subject N, like B, started fairly low in errors at the beginning, but finally he was able to reach a lower point than was B. He was able to send most of the shots within the first four small holes when he stopped. Improvement was gradual for him and there was no indication of any plateau in his curve.

Curve XIVb shows the progress of learning of subject Q. As was true of him in the previous experiment, he started the learning with exploratory acts. Several different ways of throwing were tried before he finally decided on a full arm swing with a side arm sling-shot motion as the best method for him. At the beginning his goal was to get every shot somewhere in the target and to aim high. With continued practice attention was turned toward noting where the shot hit and then trying to correct the next one with reference to it, throwing it higher or lower or with more or less force. Incentive increased with increase in success and aim came to be directed toward the 4-inch ring. An easy flat swing reaching out toward the target was used. His curve shows rapid progress, though with much wide fluctuation at the beginning, and more gradual improvement later on. When he stopped he also was able to send most of the shots into the first four small holes. There are irregular ups and downs in his curve correlating chiefly with variation in attitude, but there is no indication of any continued plateau.

A review of the curves obtained in this experiment on learning the simple motor skill of throwing a shot into a target shows that

1. When the subject took an exploratory attitude in beginning to learn the skill and tried out different ways of attacking it, there was a very rapid fall at the beginning of the learning curve making the first part of the curve appear rather steep. When, however, a learner deliberately adopted a particular method early and adhered to it, progress was more gradual and the beginning of the curve, although relatively more steep than the other portions,

was not as steep as in the curves of those who took an exploratory attitude.

2. Excepting in the case in which a peculiar method was adopted and a period of non-progress or, rather, loss of progress resulted, there was no indication of a plateau in the curves.

E. EXPERIMENT 7

Complex Skill, Involving Timing and Throwing Operating Successively and with Throwing Dependent on Timing

a. *Procedure*

In this experiment the simple skills described in experiments 5 and 6 were combined into a single complex skill in which throwing followed timing and success in throwing depended upon success in timing. The apparatus used included all the parts shown in Figure II and described in Section IV, A, of this report.

Six subjects participated. Three of them (B, N, and Q) were the same individuals who had participated in experiments 5 and 6 and were therefore familiar with the part processes involved in this complex learning. The other three (Hs, Kf, and Wg) were wholly unacquainted with any part of the problem before beginning practice on the complex task as a whole.

The procedure followed that described for experiment 5 excepting that a shot had been placed in each of the holes or pockets of the rotating disc and, instead of trying merely to strike the pocket with his tongs, the subject was required to pick up the shot as it passed by and throw it into the target, aiming, as in experiment 6, to make it enter the smallest concentric ring possible. One hundred trials were given each day at the same hour, five days per week, and errors were measured as before by position of ink spots on cards for errors in timing and by number of shots falling into the various tin troughs below the corresponding target rings for errors in throwing. Values were computed for each of the part processes as in the two preceding experiments.

Table III shows the results of learning for one subject, Kf, and is included here in order to illustrate the method employed in tabulating and computing the data obtained. The numbers given

TABLE III

LEARNING OF COMPLEX MOTOR SKILL

Practice Period	Error in Time	Number Picked	Values Assigned Target Rings: .5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	9	11	14.5	Throw Error Value	Combined Error Percentage
			Diameters of Target Rings: 2	4	6	8	10	12	14	16	20	24	34		
1	5.63	29	0	1	1	1	0	4	5	2	1	0	14	9.94	87.82
2	5.44	29	0	2	2	2	4	0	0	0	0	4	15	10.13	86.85
3	3.11	50	0	0	3	1	4	5	3	1	1	5	27	10.78	88.81
4	2.09	46	1	4	1	3	4	2	3	0	0	3	25	10.02	56.88
5	3.76	38	0	2	2	1	0	0	2	3	1	1	26	11.69	74.06
6	2.80	50	0	2	1	4	1	4	2	2	1	5	28	10.88	66.29
7	1.80	58	0	0	1	0	2	1	1	2	0	4	47	13.14	65.98
8	2.01	53	0	0	0	1	1	0	5	4	3	3	36	12.24	64.42
9	2.27	39	1	0	0	0	0	1	2	2	0	1	32	13.02	68.69
10	1.66	52	0	2	1	2	0	1	3	3	2	2	36	11.91	61.83
11	2.29	51	1	0	0	0	1	1	5	1	4	2	36	12.31	67.17
12	1.61	60	0	0	0	0	3	2	0	3	6	10	36	12.20	60.69
13	1.58	55	1	0	3	4	1	7	1	4	3	3	28	10.28	53.14
14	1.24	54	0	0	4	3	2	1	4	6	8	5	21	9.91	48.71
15	1.38	56	0	1	1	0	0	3	3	7	2	6	33	11.67	56.66
16	.72	71	1	5	1	4	3	9	8	8	8	7	17	8.32	38.04
17	.97	67	0	2	5	6	4	5	9	8	4	8	16	8.18	29.73
18	1.53	49	0	2	4	4	5	8	8	9	1	1	7	6.79	38.54
19	1.01	58	1	0	10	8	4	4	6	6	6	5	8	6.91	35.25
20	1.78	53	0	3	3	10	3	3	7	10	3	6	5	6.56	40.76
21	1.04	66	0	4	9	7	8	8	11	4	7	2	6	6.12	32.52
22	.98	59	0	1	1	10	10	12	6	9	7	0	3	6.09	32.07
23	.81	61	0	1	8	13	9	6	9	3	1	3	8	5.88	29.39
24	1.33	51	1	2	4	8	7	8	4	7	2	2	6	6.26	35.63
25	1.57	58	1	4	1	7	5	13	9	7	2	3	6	6.54	38.82
26	.89	53	1	2	0	4	11	6	12	7	3	4	3	6.09	30.69
27	.97	62	0	0	3	4	16	9	5	10	6	5	4	5.61	29.95
28	.66	62	2	4	1	8	3	15	10	4	7	4	4	6.10	30.84
29	1.31	54	0	2	4	8	11	8	7	5	2	2	5	6.05	34.65
30	.92	60	0	0	4	5	5	10	7	11	7	3	8	7.37	36.19
31	.93	59	0	1	8	11	7	7	6	8	3	4	4	6.45	32.79
32	.79	58	0	0	3	8	7	10	12	3	7	3	5	6.12	30.30

under different target rings are absolute numbers of shot caught, not percentages. Throw error values are calculated as in Experiment 6. The combined error percentage is calculated as in Experiment 4. A number in parenthesis beside a practice number indicates the length of vacational break preceding that practice. Similar tables were made for each subject and are on file in the General Library of the University of Michigan for the convenience of any persons who may be interested in studying them.

TABLE III—*Continued*

Practice Period	Error in Time	Number Picked	Values Assigned Target Rings: .5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	9	11	14.5
			Diameters of Target Rings: 2	4	6	8	10	12	14	16	20	24	34
33	.65	64	0	1	3	4	11	14	10	13	4	3	1
34	.65	60	0	0	0	6	5	8	13	10	9	5	4
35	.73	57	0	2	2	4	10	9	15	6	1	7	1
36	.49	62	0	1	4	7	7	13	10	9	8	2	1
37	.64	49	0	1	5	12	6	7	5	5	4	4	0
38	.85	63	0	1	2	11	7	11	6	17	5	1	2
39	.84	52	0	1	0	8	6	6	11	6	8	5	1
40	.73	54	0	2	5	8	10	11	4	8	6	0	0
41	.52	59	1	2	0	6	13	13	6	7	9	2	0
42	.45	71	2	0	5	10	6	10	18	7	7	4	2
43	.55	64	0	3	4	8	8	9	10	11	8	1	2
44	.35	76	0	1	7	12	14	14	7	6	11	1	3
45	.33	76	0	1	5	13	7	16	16	7	7	1	3
46	.33	63	0	0	4	9	12	11	11	7	3	3	3
47 (14)	.37	63	0	4	11	15	11	9	2	1	6	1	3
48	.79	59	0	2	5	8	10	7	6	8	9	2	2
49	.84	56	1	4	2	3	14	9	6	8	6	2	1
50	.61	63	1	1	5	13	14	6	7	4	3	4	5
51	.59	66	0	8	8	17	12	3	7	4	5	2	0
52	.77	59	1	4	3	13	7	4	12	6	6	1	2
53	.57	55	0	5	9	9	3	5	3	9	7	2	3
54	.57	68	1	6	10	17	13	9	2	2	6	2	0
55	.68	61	0	7	11	20	6	4	2	4	4	3	0
56	.61	60	0	5	7	15	15	6	3	2	6	0	1
57	.97	49	3	4	8	11	5	2	5	3	5	2	1
58	.43	67	0	4	5	9	23	8	8	3	5	1	1
59	.54	66	0	1	11	17	14	10	6	1	3	3	0
60	.66	64	0	1	11	16	12	7	8	1	3	3	2
61	.72	58	2	4	9	10	8	5	3	3	7	5	2
62	.43	66	0	3	6	12	15	8	5	6	7	2	2
63	.29	76	0	1	9	22	16	7	5	10	5	1	0
64	.42	65	1	5	8	13	16	9	3	5	4	1	0
65	.29	71	0	6	12	13	14	11	7	2	3	1	2

Practice Period	Throw Error Value	Combined Error Percentage
33	6.13	34.09
34	7.32	33.58
35	6.22	34.15
36	5.00	23.37
37	4.50	22.80
38	5.76	29.08
39	6.61	32.61
40	5.33	26.77
41	5.88	26.48
42	6.09	27.17
43	6.00	27.71
44	5.81	25.19
45	5.91	25.41
46	6.02	25.83
47 (14)	4.91	21.96
48	4.96	25.88
49	5.36	32.85
50	5.07	24.70
51	4.22	21.29
52	5.38	27.39
53	5.76	26.59
54	4.46	22.03
55	4.39	22.73
56	4.53	22.65
57	4.74	26.97
58	5.06	23.06
59	4.71	22.79
60	5.02	24.69
61	5.41	26.97
62	5.67	25.39
63	4.97	21.48
64	4.46	20.70
65	4.70	20.45

All of the tables for individuals were combined into a single table, Table IV, by dividing the total number of practice periods for each subject into thirds and finding averages for each third in each item. This shows the relative amount of skill acquired and the general distribution of errors at these three stages of the learning process. In this table there are two horizontal rows across the top indicating the target ring diameters and the corresponding values assigned them. The columns, in left to right order, show subjects, practice period numbers, average timing

TABLE IV

LEARNING OF COMPLEX MOTOR SKILL

Subject		Practice Periods	Average Error in Time	Diameters of Target Rings: 2	4	6	8	10	12	14	16	20	24	34	Average Daily Throws	Average Throwing Error Value	Average Combined Percentage Error Value
				Values Assigned Target Rings: 5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	9	11	14.5			
Acquainted with Part Processes	B	1–10	.31	3.9	9.9	13.2	16.9	10.4	7.1	5.0	4.3	5.9	2.9	3.7	83.2	4.78	72.234
		11–20	.16	3.2	6.4	13.6	17.4	15.5	10.8	7.4	4.5	5.8	3.0	1.4	89.0	4.73	54.458
		21–29	.12	4.1	11.1	16.8	19.2	14.0	8.3	5.5	5.1	5.8	2.1	1.3	93.3	4.33	44.465
	N	1–11	.31	3.3	9.6	13.2	18.7	13.1	8.7	6.0	5.4	2.6	0.7	1.4	82.7	4.25	69.699
		12–22	.09	4.0	11.3	15.0	20.2	21.1	11.2	6.5	2.9	1.2	0.2	0.0	93.6	3.85	44.750
		23–32	.02	3.7	10.9	17.8	22.8	20.5	13.6	6.0	3.2	0.6	0.0	0.0	99.1	3.79	37.469
	Q	1–12	.30	4.5	14.1	13.8	16.5	12.3	9.8	5.9	4.1	3.0	0.4	0.7	85.1	3.94	51.197
		13–24	.08	5.0	14.4	17.1	19.9	14.6	8.2	6.2	4.5	2.3	0.4	0.6	93.2	3.81	41.833
		25–35	.08	4.7	13.7	18.0	21.6	12.8	8.0	6.7	5.6	1.6	0.0	1.6	94.3	3.89	41.452
Unacquainted with Part Processes	Hs	1–23	.48	2.6	7.6	11.4	12.0	10.7	9.3	6.1	4.8	3.0	2.4	15.0	84.9	6.23	47.398
		24–45	.11	3.4	10.2	12.6	15.5	11.5	11.5	7.9	5.5	8.1	4.3	2.3	92.8	5.00	29.821
		46–67	.06	4.1	12.7	16.5	18.9	15.3	9.8	6.8	6.2	4.9	1.1	0.3	96.7	4.14	23.286
	Kf	1–22	2.12	0.2	1.4	2.4	3.2	2.7	3.7	4.3	4.3	3.1	3.8	22.8	51.9	9.87	57.041
		23–44	.80	0.3	1.4	3.3	8.2	8.3	9.8	8.9	7.7	5.4	3.0	3.2	59.5	6.27	30.556
		45–65	.56	0.5	3.6	7.6	13.1	11.8	7.4	6.0	4.5	5.2	2.0	1.6	63.3	5.19	24.371
	Wg	1–22	.62	4.2	12.1	14.8	15.2	9.3	6.0	5.2	2.6	1.9	1.6	8.8	81.7	4.89	57.581
		23–44	.17	4.0	12.3	14.4	16.8	11.6	8.8	8.5	4.3	3.9	2.0	3.3	89.9	4.54	41.993
		45–65	.03	6.5	14.1	17.6	19.7	16.2	11.8	5.6	3.8	1.6	0.5	0.5	97.9	3.75	30.295

scores, average number of daily throws into each ring, average number of total daily throws, average values assigned the throwing errors (calculated as in Experiment 6), and finally the average combined percentage of error in the performance of the complex act. This final item was computed for this complex skill by the method described for the complex skill in Experiment 4.

The results obtained for each subject are shown in curves XII–XIVc, d, e, and XV–XVIIa, b, c, in which the divisions on the horizontal axes represent practice periods and those on the vertical axes represent error values. In each case, the curve for complex learning and the curve for each of the part processes involved are given.

b. *Discussion of Results*

The purposes of this experiment were (a) to obtain a curve for learning a complex motor skill in which the component parts operate in sequence and success in the second is dependent upon success in the first, and (b) to compare the curve obtained when the simple elements of the complex skill are known to the learner with that obtained when the whole task is entirely new.

Three of the subjects (B, N, and Q) *had practiced the component parts as separate skills* early in the school year and began learning the complex task after the winter vacation. The length of interval between the end of practice on each simple process and the beginning of practice on the complex task for each of these subjects is

Subject	Timing	Throwing
B	5 weeks	1 week
N	6 weeks	2 weeks
Q	6 weeks	2 weeks

At the beginning of complex learning these subjects, like those in Experiment 4, experienced some strangeness in the situation, but were not as upset over it as was the earlier group. The action was not smooth at first, of course, but they were not much disturbed by that. Comments made on the first day in the complex task indicate that they regarded the work as similar excepting that several acts had to be performed in rapid series instead of pauses

after each simple act. All claimed that the learning of the simple processes had helped them.

Curves XIIc, d, e, represent the learning of the complex task by subject B. He remarked that from the very beginning the task "seemed little less than the combining of all the things I had been doing before. Of course, there was the question of combining the actions into a smooth stroke, but that came with experience." The work was easy for him and he continued with the attitude of wanting to see what would happen with practice. Having to pick up a shot from a moving board was new, however, and the results of the first day showed that some adjustment to the situation was required. His curve of the complex act (XIIe) shows an early rapid decrease in errors followed by continually more gradual progress. He regarded the task as a smooth whole consisting of two parts, but not disjointed. Analysis of the curves of separate processes shows that in timing (curve XIIc) he began higher in error than when he stopped practicing timing alone as a simple process. This higher error score at the beginning may have been due in part to lapse of time after the last practice, but was probably due partly also to the necessity for coördinating. By the end of practice on the complex task he had attained a lower score in timing error than when he learned timing as a separate skill. This probably can be explained by the fact that when he practiced timing alone he was striking at an empty hole, but now he had to pick up an object from the hole, and it was easier to observe success immediately when there was something to get hold of than when striking at empty space. The throwing curve (XIId) after the 5th practice also contains an elevation in error score, though not a big one. It will be recalled that in practicing throwing alone B had a similar elevation in his error score. This seems to be an individual peculiarity of this subject in continuous learning. He made a better record when the situation was new and interesting but, with repetition of the same act day after day, interest waned and results were affected. It should be noted also that the final throwing error score reached at the end of practice on the complex skill was at a somewhat lower level than that reached in

practicing throwing alone. On the whole the curve of complex learning shows a rapid fall at the beginning and gradual improvement with continued practice until a limit was reached. There was no plateau of any sort in the curve.

Subject N, whose learning is shown in curves XIIIc, d, e, regarded the complex skill as a single act. When he was learning the simple processes they had no relation at all to each other in his thinking, but when he tried to combine them in the complex task they readily formed one act for him. The learning of the simple acts helped him in learning the complex skill. From the very beginning he took the task quite easily. Timing to pick seemed natural before throwing, so he just picked and threw. At first, however, he did find it a little difficult after each throw to come right back to wait for the next shot. This was shown by the objective data, for during the early period of complex learning his throwing error score was relatively higher in comparison with the corresponding score at the end of simple learning than was true for time, although throwing was the skill which had been more recently acquired. This difficulty was soon overcome and progress was rapid for several days after which, with continued practice, it became more gradual. Analysis of the separate curves of the part processes indicates that the subject was able also to reach a standard of skill in timing better than the timing skill attained when learning the simple action alone. Probably the explanation given for subject B holds true for N also. When practice ceased he had acquired so high a degree of skill that he was able to pick 98 to 100 out of 100 shots. The action was easy and automatic and, as he said, the whole action took place more or less without thought. Whenever he tried to pay attention to either part of the act the results, instead of being better, were worse. After the first six days his throwing reached a skill not quite as good as in his simple learning and continued so until the end of practice. This seemed to be the limit for him in throwing. In general, he did not pay attention to separate parts of the complex act and there is no portion of his learning curve which may be called a plateau.

Curves XIVc, d, e, show the learning progress made by subject Q. On the first day of practice he remarked that he was taking quite naturally to the task and not having much trouble. Nevertheless, he was paying more attention to timing than to throwing during the first few days. Though more or less he regarded the situation as a whole, it somehow seemed of two parts, too, picking at the right time and throwing. He tried especially to apply his former methods of timing and of swinging the tongs in picking up the shot. Soon he discovered that conscious singling out of one part disturbed the whole act, so he tried just to watch for the appearance of the white card and after an interval, not consciously timed, to pick. This proved very successful. The two, timing and throwing, had become really one act for him. The elevation for practices 6–9 in his complex learning curve was caused by a series of unfortunate conditions. Analysis of his responses shows that during this period both timing to pick and throwing were less well done than before. First there were poor results caused just by an " off " day. The subject could not tell what was wrong but just could not improve. On the following day he took an " I-don't-care " attitude, simply made the responses without really trying to improve. On the third day an embarrassing experience before coming to the laboratory had upset him emotionally and he was very inattentive. On the 9th practice he was tired. When on the next day he was relaxed again and at ease, his results were better. The cumulative effect of these factors is reflected in his curve of learning for those days. When all was well with him and he was trying to learn, but not over-anxious, his results showed improvement. Analysis of results in the separate processes of this complex skill shows that he regained his original skill in timing within two days and, at the end of practice on the complex task, was able to do better than he had done when practicing timing alone. The same explanation offered for other subjects applies here. Apparently he had done his best in throwing when learning that act alone and when he was combining, after the above-mentional upsetting days had passed, he nearly, though not quite, regained his former skill and continued at that level until the end. His

curve of errors in the complex skill falls rapidly at the beginning (the fall from the first practice to the second being much greater than it was for N, and Q took more of an exploratory attitude than N did) and was more gradual thereafter. Excepting for the elevation caused by unusual conditions, a limit was soon reached and retained. There was a period of loss of progress due to factors already accounted for, but there was no evidence of a plateau in the ordinary sense of the term.

In summary, the results for subjects learning this complex task made up of a succession of separately learned simple acts indicate that

1. The subjects were able to regard the situation as a whole, although there was some feeling of newness in the task. The problem was accepted quite naturally as one complex of two parts not disjointed. This ease in adjusting to the new complex situation is probably to be explained by the nature of the skill itself. Because the factors operated in succession, all the learner needed to do after having learned the component parts was to connect them into a single sequence. The only overlapping was that picking had to be done along with timing or, in other words, timing was expressed by the act of picking.

2. All the curves indicate that learning the simple elements did help the subject learn the complex task and that, as attention was distributed equally over the two parts, there was no evidence of any plateau.

3. One subject showed better results in throwing in the combined task than in the simple task, but his record in the simple task had been poor. The other two were not quite as effective in throwing in the combined as in the simple task. All showed better final results in timing in the combined task which is probably to be explained by the more exact appreciation of success because of having to pick up the shot.

The other three subjects who learned this complex skill (Hs, Kf, and Wg) had *no previous acquaintance with any part of it.* All took it as a game and were eager to improve their records from day to day. The task was regarded as a unified whole from the start, though they were aware of the presence of two

elements and at first more attention was given to timing to pick than to throwing. This was true for each subject, but for some it continued longer than for others. In learning the skill several problems were involved. First, a proper position and posture had to be found so that the subject could pick up the shots and throw them comfortably and efficiently. Moreover, it was necessary to handle the tongs properly so as to pick easily and to throw with a comfortable swing which would bring good results. All these skills had to come gradually. Some were carefully thought out, others were accidentally hit upon and later adopted. The task was not an easy one, but it was not difficult enough to cause prolonged disappointment. Some subjects were able to reach a higher level of attainment than others. The problem which at the outset seemed awkward and required concentration of attention developed into a skill performed most of the time without much conscious effort and finally rather automatically. The learning of individual subjects is shown in curves XV–XVIIa, b, c.

Subject Hs was proficient in sports and in music—piano and cello—and so had some previous experience in throwing and timing. His learning started with attention first centered on timing, even though he recognized the task as a unified complex act. There was little real aiming at first. As timing became easier more and more attention was given to throwing. In timing he let the tongs touch the raised edge about the white card just before the card came into view, as this seemed to prepare him for the task, and then, after seeing the card, he estimated the time and tried to pick. His standing position was found to be an important factor. A slight shift made it difficult to time and pick exactly and caused the throw to swerve to one side. His learning curves (XVa, b, c) substantiate his introspections in that for the first four weeks timing was improving, at first rapidly and then gradually, while throwing was at a standstill. Then, after timing had become fairly successful, throwing improved suddenly, though with fluctuations, while timing progresses a little more slowly. After this the two seemed to improve together. Timing reached a final level earlier than

throwing, but there was improvement in the total skill until both were learned. His curve of complex learning (XVc), although it does not contain an extensive plateau at the beginning, does show that improvement was not very rapid after the first five days. However, after the 20th period when the sudden fall in errors occurred, the total curve also fell and from then on improvement was gradual. There was a two-week vacational break at the 49th period, but no more loss occurred there than was present in day to day fluctuations. At the end, timing had approached a dead level and throwing was improving only a little, so the total curve represents his limit. It is evident that for him attention to one part more than to another at the beginning of learning caused slow improvement and that, when attention was more evenly distributed, better general improvement resulted. The total curve slopes gradually until the limit was reached. The introspections of this subject indicate that after the beginning the task was regarded as a single complex whole and not as of two parts. By the end a degree of skill had been reached which insured smooth and fairly automatic action.

Curves XVIIa, b, c give the course of improvement for subject Wg in learning the skill. He had been interested in sports and had mechanical experience requiring precision in timing and in speed which seems to have aided in mastering this problem. He proceeded on the assumption that it was necessary to adapt his movements to those of the apparatus. There were the problems of getting a comfortable stance, of holding the tongs correctly, of timing instantly with the appearance of the white card, and of throwing the shot into a small hole. The position was accidentally found and thereafter retained; timing was established by counting up to a certain number and then picking. Wg found that if he waited to see the shot before picking he would be too late, but he was able to adopt a counting system which helped him during the first few weeks after which timing was an automatic act. In the early weeks the task, though regarded as a complex whole, seemed nevertheless to consist of two parts, but later it was just one task. Looking at curves XVII a and b, we find that at the beginning there was more improvement in timing

than in throwing. In fact, throwing was at a standstill for almost six weeks. After timing had reached some degree of success, throwing began to change somewhat and for a period there was irregular fluctuation. This probably was due to the fact that the subject was trying to find a good method of throwing and wrong habits already developed had to be overcome. Throwing errors finally began to fall rather abruptly at about the 35th practice period. When the curve of throwing errors fell, the complex curve (XVIIc) showed a corresponding fall. In this case again we find a delay in improvement in the total skill with a consequent plateau caused by special attention to one component, but when attention was more evenly distributed the total complex curve went down. By the time he stopped practicing this subject had reached a high degree of skill in picking and was throwing most of the shots within the four smallest concentric rings. The act was performed easily and more or less automatically. A two-week vacation showed no effect in timing and there followed only a very temporary disturbance in throwing.

Subject Kf during the whole learning process regarded the problem as consisting of two connected parts. At first he centered attention mainly on timing; then after about three weeks he attended to throwing also. Thereafter until the end of practice attention was given the two acts together. His learning curves (XVIa, b, c) substantiate this statement of method given in his introspections. For the first three weeks improvement in timing was rapid but throwing was at a standstill, after which there was a sudden fall in the curve of throwing while timing improved more gradually. The two skills then improved together with continued practice. His curve of complex learning (XVIc) shows a period of slow progress at the beginning which was caused by non-progress in throwing, but when sudden improvement in throwing occurred a corresponding fall appeared in the total curve. After that the total curve sloped gradually until a limit was reached. Kf started at a much higher level of error and ended at a lower level of efficiency in the skill than did the others. Although his level was different, he had made no less improvement than the others, but the task seemed to be more

difficult for him than for them. He often remarked that his previous experience in timing had never been very precise, and he was not precise in timing in this problem. Also he threw more widely than the others, both at the beginning and at the end of learning. His curve, like the curves for the other two subjects, shows that when attention was directed specifically to one component, improvement in the total act was retarded; when attention was well distributed, there was improvement in the skill as a whole. A vacation of two weeks after the 47th practice made no apparent difference in his skill.

A comparison of the curves for the subjects who had learned the simple elements separately before taking up the complex task (curves XII–XIVc, d, e) *with the curves for those who took it up as an entirely new experience* (curves XV–XVIIa, b, c) shows that when one was already acquainted with the elements there was no need of attending to them separately, consequently the total curve contained no plateau. When, however, one was unacquainted with the elements, there was a feeling of having to attend first to one and then to the other, and as a result plateaus appeared.

V. SUMMARY AND CONCLUSIONS

A. GENERAL STATEMENT

The general purpose of the present investigation has been the study of plateaus in learning curves for motor skill. More particularly, it has been to discover under what conditions plateaus appear. The term "plateau" has frequently been defined as a period of little or no progress. In most of the literature, however, writers appear to have in mind long periods of non-progress when they use or define the term, though M. D. Smith seems to have applied the term to intervals as short as six practice periods. In this study the term is used to include both long and short periods of non-progress, but it is recognized that they may be different in character.

The specific purposes of this investigation have been to discover whether periods of non-progress appear at all in curves of simple motor learning, to see how the separate elements are acquired during the learning of a complex skill, and to discover, whenever plateaus do appear in the curve of complex learning, what occurs with respect to the separate elements. The skills employed in this study differ from those used by Batson in that our simple learning tasks are the very same ones involved in the complex task, whereas Batson's simple tasks of time, direction and force, although intended to correspond with the separate elements in ball tossing, may not really be the same. The two studies are similar in that the two complex tasks employed are constituted in each case in such a way that the simple factors operate simultaneously in the one and successively in the other. Even in this respect, though, some difference exists. In our experiment in which the factors work simultaneously, a subject may attend to one element if he chooses. This study differs from that of M. D. Smith in that in his ringball game the elements

were added one after another during the course of learning, whereas in our experiment the factors are learned separately first and are afterwards combined into the complex task.

B. PLATEAUS

The complex tasks are of such a nature that in both cases the subject may attend either to separate factors or to the whole. Plateaus representing long periods of non-progress have been found in some of the curves of complex learning. In the complex motor skill which involved the three factors—time, direction and force—and in which the factors operated simultaneously, we find two intervals of very little progress in the learning curve for subject Mg (curve Xd). In the interval between the practices 2 and 10 this is explained by the fact that attention was directed to time alone. Curves plotted of each of the part processes in this complex learning (curves Xa, b, c) indicate that time was improving during that interval, but that there was little change in force and direction. After the 10th practice force improved more, time still improved somewhat, but direction was at a standstill. Hence the curve of complex learning shows a second plateau on a lower level of error between the 10th and 20th practices. Introspections and objective data both point to the fact that, when attention was directed to separate factors, the total curve did not show much improvement.

In the curves for the subjects who learned the complex skill of timing to pick and throwing shot into a target we again have plateaus of relatively long duration. In curves XVa, b, c, showing acquisition of skill by subject Hs in the two part processes involved, we see that during practices 1–20, which covered a period of four weeks, timing improved rapidly at first and then more gradually, but throwing remained at a standstill. After the 20th practice throwing began to improve more rapidly and timing more slowly, until the 35th practice when the two began to improve together. Here we find in the curve of complex learning (XVc) a period of relatively slow progress somewhat obscured at first by the very rapid progress in timing, but

still showing the effect of improvement in only one factor. After the 35th practice the curve sloped downward gradually with both factors improving together. Here again the report of the subject indicates that attention was directed first to the separate element of timing and then later was more evenly distributed over the two processes at once.

In curves XVIa, b, c for subject Kf there is a plateau between practices 2 and 15 followed by a sudden fall. Curves of the part processes show that during this period timing was improving rapidly but throwing was more or less at a standstill. After the 16th practice the two progressed together and the complex curve shows gradual improvement. Introspections confirm the objective data, showing that attention was directed first entirely to timing and then was more nearly equally distributed over the two elements until the end of learning.

Curves XVIIa, b, c for subject Wg also show a relatively long period of non-progress in the early portion of the complex curve. Curves of the part processes indicate that during the first six weeks there was considerable improvement in timing but very little in throwing; then throwing improved and timing progressed more slowly. The complex curve slopes downward after the 33rd practice. The elevation in the curve between practices 52 and 55 occurred just after the winter vacation break. The comments of the subject confirm the objective data showing attention directed first to timing and later more nearly evenly distributed. In this complex skill timing could not be neglected even after a considerable degree of efficiency had been reached, for one had to time correctly in order to pick up the shot for throwing.

In Type I, Experiment 4, subjects F, M, Hy, and T, for whom the complex skill was entirely new, and all those subjects who had mastered the simple factors separately before commencing to learn the complex skill (K, L, W, H, Kl, and Ws), did not have any long plateaus in their learning curves. Curves plotted to show performance in the part processes during complex learning indicate that all factors were improving together, although some, such as force, were mastered earlier than others. Intro-

spections substantiate these data; attention was evenly distributed over the parts in the complex task.

From the data obtained it seems clear that the results are in agreement with the findings of Batson, that when attention is directed to separate parts at different times in the learning of a complex motor skill plateaus appear in the complex curve and when attention is evenly distributed there are no plateaus of appreciable length.

Where the factors of a complex skill operate simultaneously the subject may attend either to all at once or to one at a time. Four of the five subjects who learned the skill as a whole with no previous knowledge of its parts were able to regard it as a whole with attention distributed accordingly. In the curves for those four subjects there is no long plateau. In the case of the one subject (Mg) who attended to the elements separately there are very definite plateaus. In the curves for subjects who had learned the component parts separately before practicing the complex task, there also are no plateaus once the difficulty of reorganizing the independent items into a unitary system had been overcome. In the task in which the factors operated in succession all the learners had a tendency to attend to one factor at a time, although the purpose of the experimenter was to have them regard the task as a single pattern. Probably this was occasioned by the fact that by the very nature of the task one could not throw the shot unless he had first timed correctly in picking it up. The curves for those learners show plateaus in the earlier portions but later, when attention was more evenly distributed, no plateaus occurred. This difference in the tasks—that in one the learner could readily choose between the two methods of attending and in the other it was almost necessary to attend to an earlier factor somewhat more than to a later one—explains the difference in the frequency of plateaus in the curves of the two learning problems.

There is another difference in these two complex skills which is of interest. The subjects who learned the first skill found it more difficult, after having learned the parts of the skill separately, to weld the once independent patterns into a single unified

whole than did those who learned the second skill. This was undoubtedly due to the temporal difference in operation of the parts. In the second skill all the learner needed to do was to regard these successively operating part processes as connected items in a complex united series, while in the first skill he had to see them as simultaneous parts of a single whole.

In addition to the long period plateaus mentioned above, there are a number of relatively short periods of little or no progress which cannot be explained either as due to the factors already named or as mere daily fluctuations. There are several causes for these short periods of non-progress. One is change in method or position used by the subject. For example, in curve IVa, between periods 6 and 12, while subject H was trying different systems of counting in order to learn to estimate time accurately, his progress was retarded. In curve Ia between periods 1 and 14 subject K tried out and gave up the counting method, and this is reflected in his curve. In curve XIIb between practices 5 and 17 subject B changed to an unfavorable stance and had difficulty in returning again to a favorable position, but when one day his position was changed only slightly improvement in his throwing score followed. Besides, he reported that for him the middle period in any work is more difficult than either the beginning or the end.

A second cause of these short plateaus is over-anxiety or, as Book has termed it, effort wrongly applied. This was a factor in the instance just described in which B, after losing his proper stance, had to try out several different positions before the correct one was recovered. In curve VIa, subject Ws showed little progress between practices 12 and 16. This was a week of tests in school subjects and lack of sleep caused poor work on the first day. The next day he tried harder but his results were worse. After his tests were over and he was more at ease improvement came. In his direction curve (VIb) this subject showed little progress between practices 6 and 12. This, too, was due to over-anxiety in a period when his progress was poor and tension was great because of school tests and lack of sleep.

A third cause of such plateaus is somewhat related to the cause just described. In a condition of tension over tests in school work some subjects were content for the time simply to maintain the level of skill already achieved and did not seriously try to improve. In the latter half of curve XIIIa, for subject N, there is a period of relatively slow progress. This subject had already reached a high level of efficiency and was satisfied to remain there during the examination period. In curve IIg, for subject L, we find a similar plateau during the examination period.

A fourth factor causing such plateaus is lack of interest and enthusiasm. In curve XIVe for subject Q between practices 6 and 9 we find an actual loss of proficiency due to this cause. In general the interest of this subject was good, for he had determined to surpass the record of one of his friends who also was serving as a subject in the experiment. In spite of this resolve there occurred a period, it will be recalled, during which a series of disturbing factors were operating to influence his learning unfavorably. The effect of these factors is reflected in his curve, showing an upward trend in errors. When, just following this interval, the subject again was composed and more relaxed, his learning improved immediately and his curve of errors continued to fall gradually thereafter.

A fifth factor causing such short periods of non-progress is the necessity for automatization of skill already acquired before further improvement could be made. It appears necessary to automatize a level of achievement sufficiently to enable the learner to relax somewhat and give attention to refinement of detail as he approaches the end of learning. This phenomenon—a period of non-progress followed by a downward slope in the error curve near the end of learning—is found in several of the curves of simple skill, IIc, IIIa, Vb, XIIIa, and XIVa.

Another factor causing rise in curves of error for some subjects is the two weeks of vacational break in practice. This was quite marked in the case of Mg (curve Xd) who was a rather slow learner. Three of the others, T, H, and Wg (curves XId, IVg, XVIIc) who had made more progress in learning up to

this time, showed only a slight set-back effect from the vacation period and this effect was very quickly and easily overcome.

Another group of short periods of little progress with large daily fluctuations is due to difficulty in changing pattern. After certain processes had come to be regarded as patterns in themselves, welding them into a single complex pattern proved difficult at first. Curves Ig, periods 2–7, IIg, periods 2–7, IIIg, periods 2–5, and IVg, periods 2–5, are all periods of little progress which appear at the beginning of practice on the complex task after the simple processes involved had been separately learned. The subjects were trying to regard the task as one complex whole. Some of the difficulty was undoubtedly due to the interval between the end of practice on simple tasks and beginning on the complex task. However, in three of the four cases the item causing most trouble was not the one having the longest interval of non-practice, and furthermore similar breaks in practice in the complex act generally caused little or no loss. In the fourth case the subject (H) was a highly distractible individual. In view of these facts it appears that the main cause was not relearning, but difficulty of combining the once independent elements into a unified complex pattern.

From the foregoing analysis of periods of non-progress, both long and short, it seems apparent that long periods are likely to appear in complex tasks whenever attention is directed specifically to separate parts one at a time, and shorter periods may appear either in complex learning or in the learning of simple motor skill. Nine of the fifteen short plateaus described above are found in the curves for simple learning. Batson concluded that in such curves no plateaus appear. Perhaps this is because he was looking for long plateaus and disregarded the shorter and less conspicuous ones. A study of his curves indicates that there are some short periods of little progress in the curves for simple learning. They are found in curves XVII (plate IV) periods 10–20 in direction, XXV (plate VI) periods 3–8 in time, and curve XX (plate VI) periods 5–9 in force. It should be noted, however, that " complex " and " simple " are relative terms. In

our Type I experiments all of the simple processes excepting force, although intended by the experimenter to be simple in nature, were regarded by the learners as involving some details of procedure which they did not master all at once. It will be recalled that in the skill of pushing the pendulum at the right time there was the problem of the best way of pushing so that it would not swing in all directions; and in the skill of sending it in the right direction there was the problem of pushing so that it would swing smoothly and then waiting until it was perfectly still before pushing again, which some learners as late as near the end of the learning period singled out as an item to be taken into consideration. Likewise in the Type II experiments in the skill in hitting the hole in the cardboard at the right moment, some subjects near the end of learning singled out such details as watching easily but carefully and hitting gently. It may have been that these details of procedure, which the learner noted so late and which apparently could not have been noted until automatization of the more fundamental process had made possible a relaxed attitude and the direction of attention to such details, caused the appearance of some of the shorter periods of non-progress in some of the simple skills. It is to be observed also that some of the causes of the shorter plateaus found in curves of simple learning and described above belong to the so-called subjective and objective factors which Smith called incidental factors and which are considered by most writers as extraneous to the learning process itself.

C. DAILY FLUCTUATIONS

Most of the curves in the present study show day to day fluctuations, though some are smaller than others. As a rule, they occur more frequently in the first half of the curve than in the second. Their degree and their frequency of occurrence in this investigation vary according to subject and not according to type of learning, excepting that in the simple learning of throwing there are more fluctuations in the curves for all subjects. Generally speaking, whenever a task caused much uncertainty and

difficulty for a subject there were more fluctuations from day to day in his curve than in the curve for a subject who found the task less difficult. These fluctuations are affected primarily by extraneous factors and, as such factors usually have more influence in the earlier part of learning, fluctuations appear more frequently in the earlier portions of the curves.

D. EFFECT OF INTERVALS BETWEEN PRACTICE PERIODS

The data obtained in this study do not show any definite effects of very short intervals between practices. It will be remembered that the subjects who learned the skills during the year 1931–1932 practiced on alternate days and had a 2-day interval at the end of each week, and those who learned them during 1932–1933 practiced five successive days each week with the same 2-day interval at the end of the week. The results show that this difference in distribution of practice made little difference in the shape of curve obtained and that the effect of the week-end interval is not at all consistent. For some subjects the week-end interval did cause a slight loss in the earlier part of the learning process, but even for them this effect disappeared when a higher level of achievement had been reached.

As to the effect of the 2-week interval, little or no loss occurred in the majority of cases, some in a few. When achievement was already high the loss, if any, was slight and recovery rapid, only one or two practices being needed to restore skill to the former level; but when achievement was lower, the loss was greater and recovery slower. Examination of curves IX, X, XI, XV, XVI, and XVII brings out this fact. Subject Mg (curve X), who was at the lower level of achievement at the vacational break following practice 49, lost more than either Hy or T (curves IX and XI) whose vacation followed practice 47 in the same learning task but who had already attained greater efficiency. Curves XV, XVI, and XVII for subjects Hs, Kf, and Wg had all reached a fairly high level in relation to final performance, and for them loss was less and recovery rapid.

E. INFLUENCE OF SUBJECTIVE AND OBJECTIVE FACTORS

Subjective and objective factors have been found by all investigators to affect learning. On bright sunny days subjects did better work; gloomy days reduced enthusiasm. Whenever a subject was doing well in college work he worked well in the experiment. Mental and physical fatigue in the final examination period was reflected in performance in the laboratory. It has been pointed out that such subjective and objective factors were the principal causes of daily fluctuations and of some short periods of non-progress. Generally their effect was felt less when learning had already reached a high level of efficiency than when it had not.

F. FORM OF CURVE

It is not the specific purpose of the present study to find the form of the curve of motor skill. However, a glance at the curves obtained does afford some information on this subject also. Often it has been claimed by writers that there is a typical practice curve of motor skill. Batson, however, concluded from his curves that there is no typical curve of all kinds of learning. The curves in the present study show that a large number of them, including curves of both simple and complex skills, do exhibit a more or less rapid improvement at the beginning followed by negatively accelerated improvement until, as the end is approached, the curve parallels the x-axis; but there are great individual variations as to extent of rapid progress, appearance of short plateaus, and other details, even for the same learning task.

Another group of curves obtained in the study shows one or two periods of slow or non-progress in the early portions. These are for the most part in those curves for complex skill in which attention is directed to different parts of the act at different times. Sometimes a sudden fall follows the plateau, but more often the fall is not so conspicuous and improvement is gradual. However, even in this group of curves there tends to be a rapid fall

at the very beginning for from one to three days and, if we overlook the plateaus, there is also negatively accelerated improvement with continued practice. Each part process shows negative acceleration after the curve has once gone down, and the complex curve represents the combination of the part curves. There is negative acceleration in each of the part curves, but it occurs in the parts in succession. Hence we may say that the two groups of curves do have the very general characteristic of rapid improvement at the beginning, followed by negatively accelerated improvement with continued practice, yet one should be careful in making general statements without qualification. There are individual differences in the details of the curves even though they do show these very general characteristics. For some learners the rapid improvement continues longer than for others, and in the same learning skill some show long or short periods of plateau, while others do not. In cases where the nature of the skill is such that attention has to follow a certain order there is more likelihood of finding resemblance among the curves for different individuals. The shape of the curve depends upon the nature of the learning task and also upon the nature of the learner. This type of learning involves much trial and error, and the shape of the curve depends much upon the method, attitude and other personal factors operative during learning.

It is obvious then that all one can say regarding the shape of the learning curve of motor skill is that there is a very general characteristic of rapid improvement at the beginning followed by negatively accelerated improvement with continued practice until the curve parallels the x-axis near the end of learning and that this general characteristic is greatly qualified by individual variations for different tasks and for different individuals.

VI. GENERAL CONCLUSIONS

From the results obtained in the experiments described in the sections above the writer feels justified in drawing the following conclusions regarding the appearance of plateaus in learning curves of motor skill:

1. Plateaus representing periods of non-progress of short duration may occur in learning curves of both simple and complex motor skills.
   a. In curves of learning of simple motor skills they are due to
      1. Conditions external to the learning process itself, subjective and objective factors, such as position of the subject in relation to the apparatus, change in method, fatigue, interest, etc.
      2. Automatization of response which brings relaxation from the feeling of tenseness and permits direction of attention to refinement of procedure near the end of the learning period.
   b. In curves of learning of complex motor skills they are due to
      1. Conditions external to the learning process itself (mentioned above).
      2. Difficulty of building up new complex patterns out of simple but formerly independent ones.
2. Plateaus representing periods of non-progress of long duration do not occur in learning curves of simple motor skills. They may or may not appear in curves of complex motor skills. In complex learning
   a. Plateaus do not appear when the learner can and does attend to the whole complex throughout the course of learning.

b. Plateaus do appear when the learner attends to separate part processes one at a time, either because the factors work in succession so that the function of one depends upon the success of the preceding one and attention tends to be led in that direction, or because the subject chooses to attend to separate factors even though they operate simultaneously.

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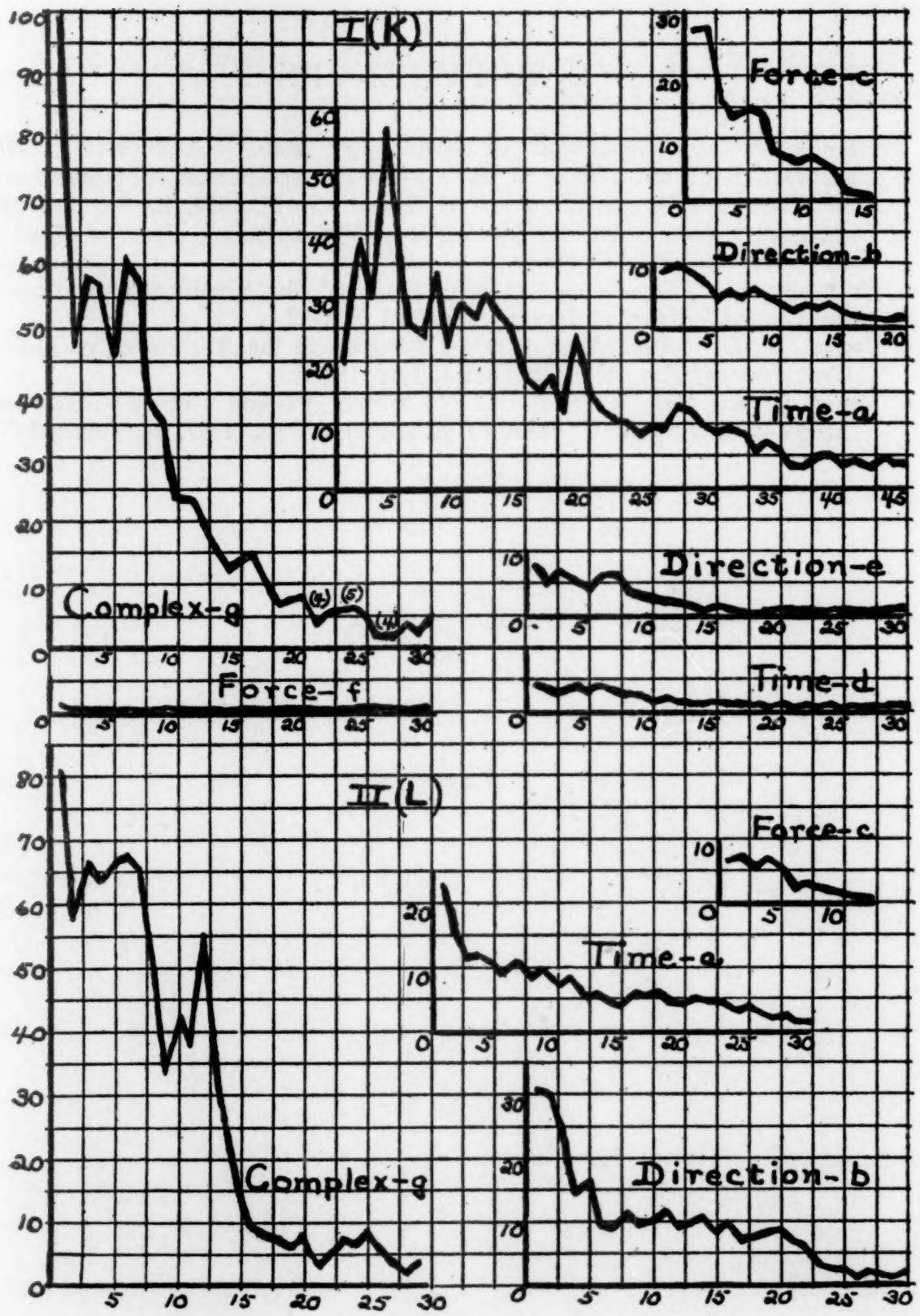
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Force-c
Direction-b
Time-a
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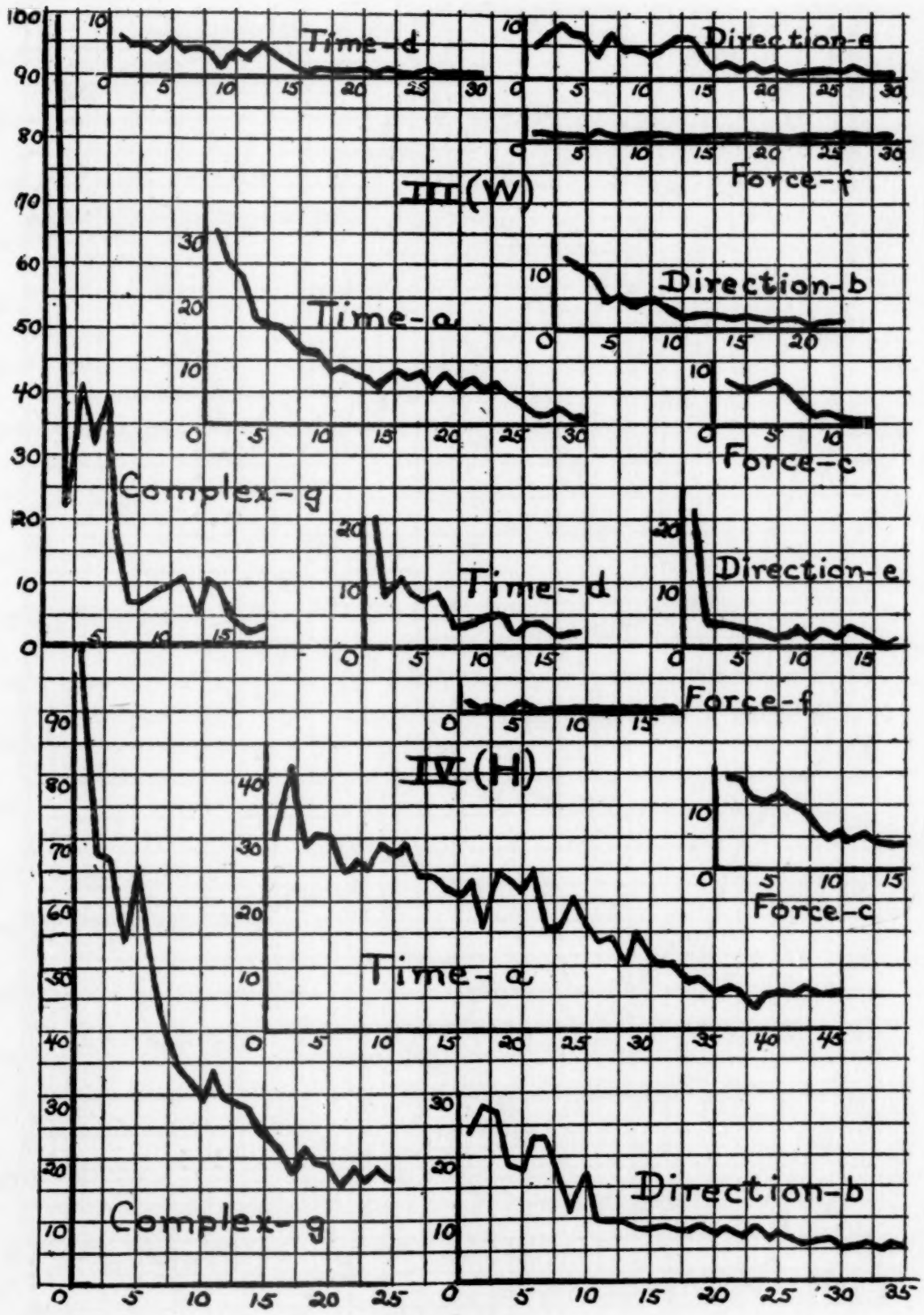
PLATE I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Direction-e
III (W)
Force-f
Direction-b
Time-a
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Time-d
Direction-e
Force-f
IV (H)
Force-c
Time-a
Direction-b
Complex-g

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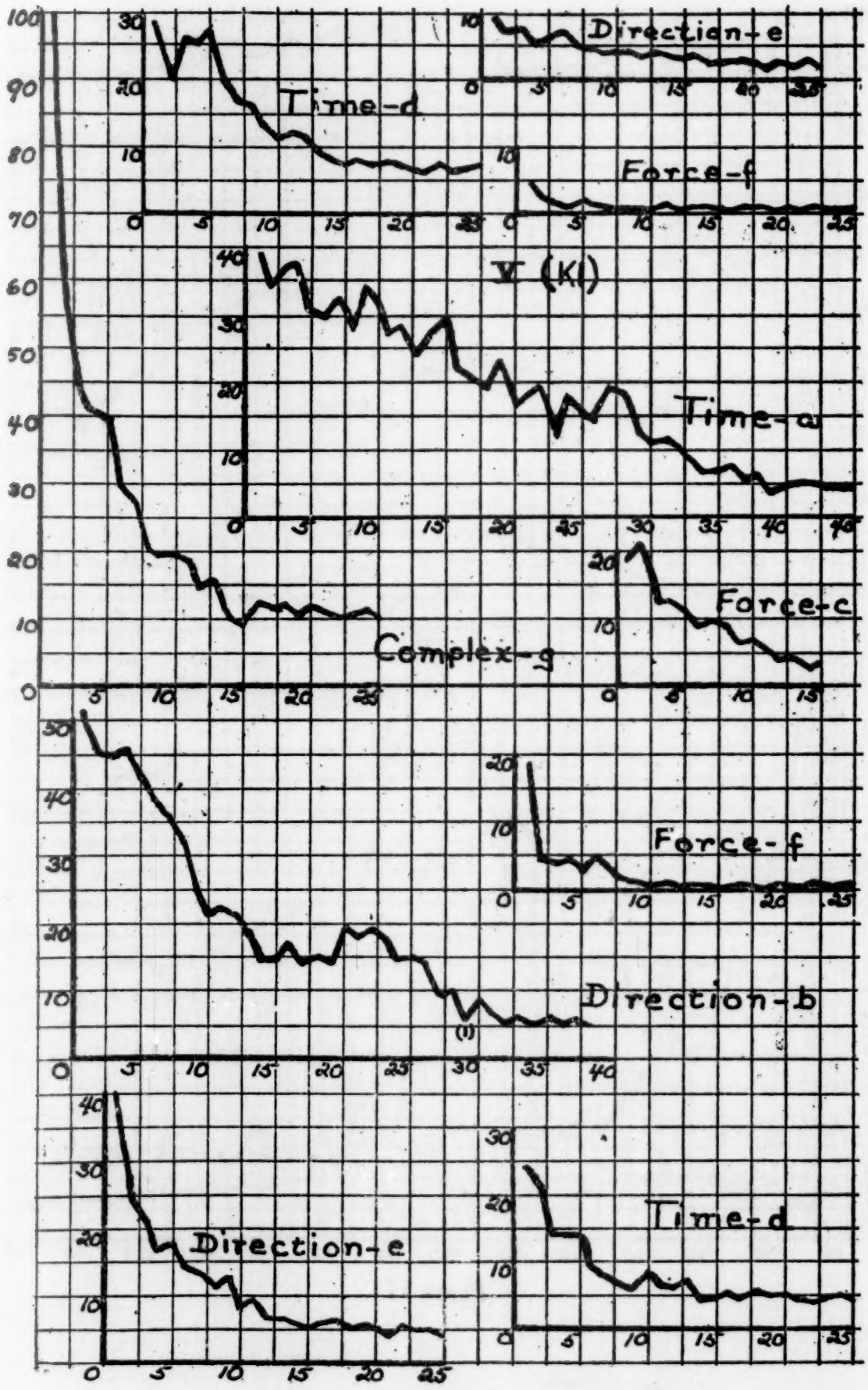
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Force-f
V (KI)
Time-a
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Complex-g
Force-f
Direction-b
(1)
Direction-e
Time-d

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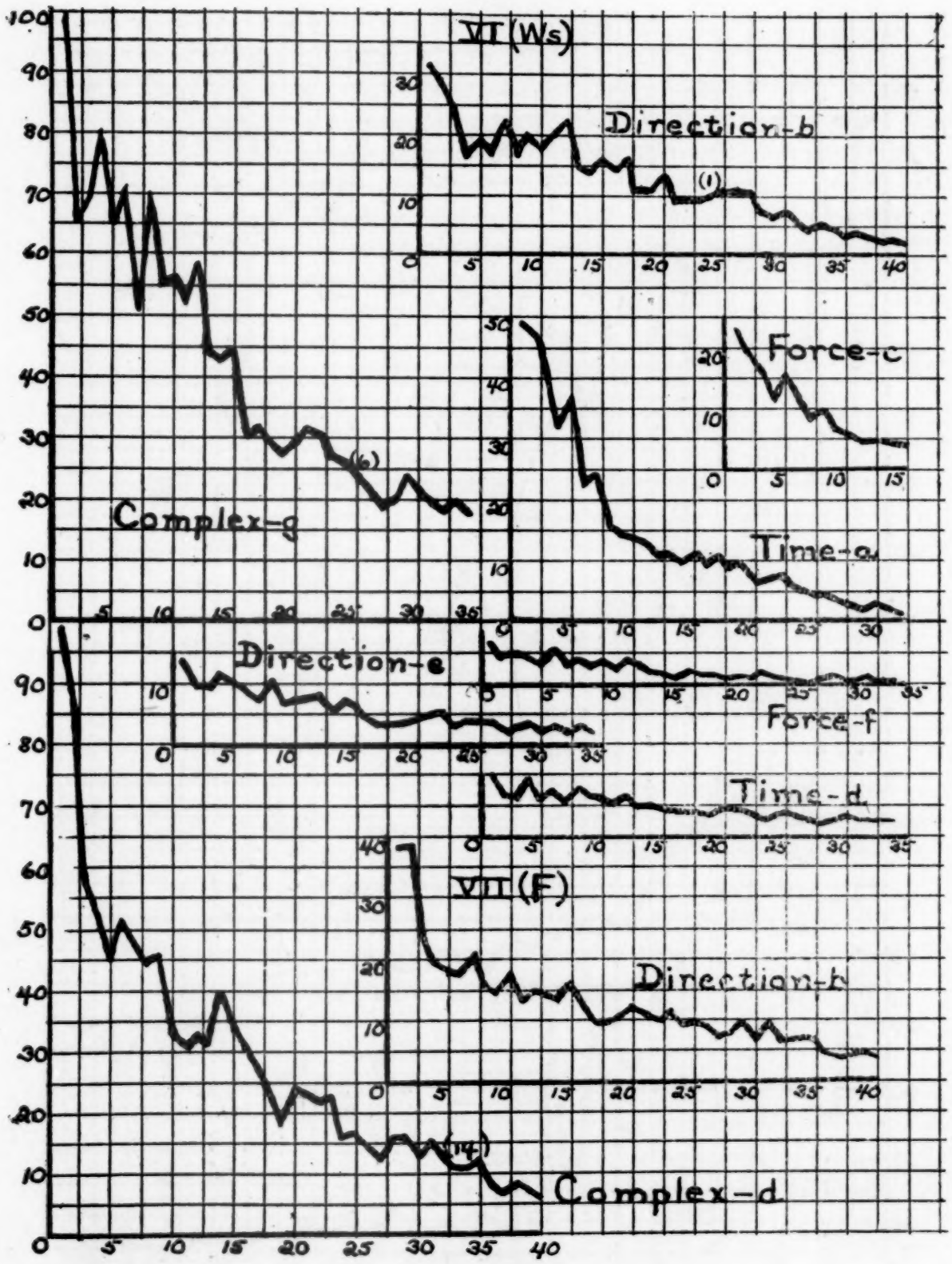
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Direction-b
(1)
Force-c
Time-a
Complex-g
(6)
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VII (F)
Direction-h
(14)
Complex-d

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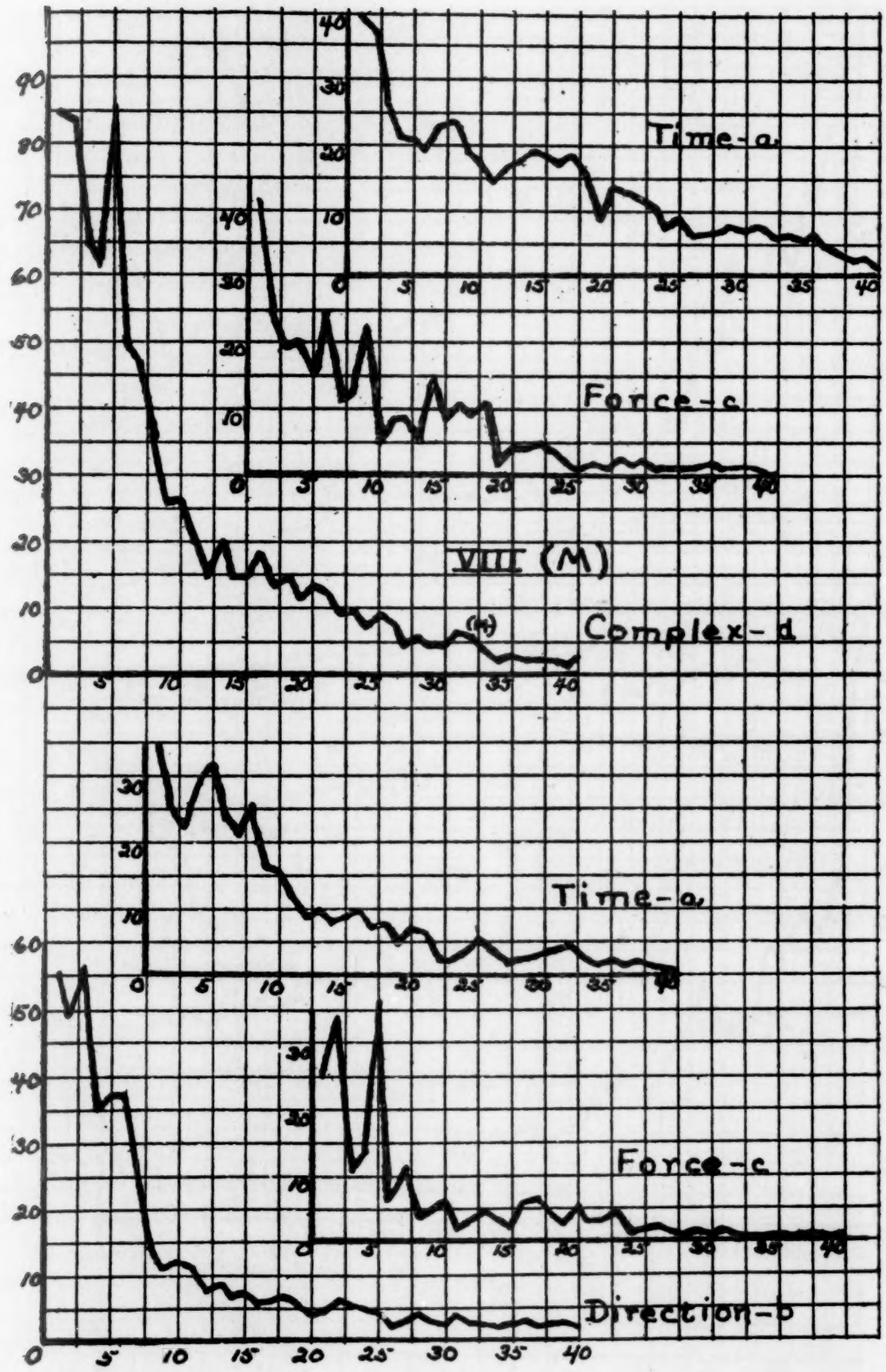

PLATE V

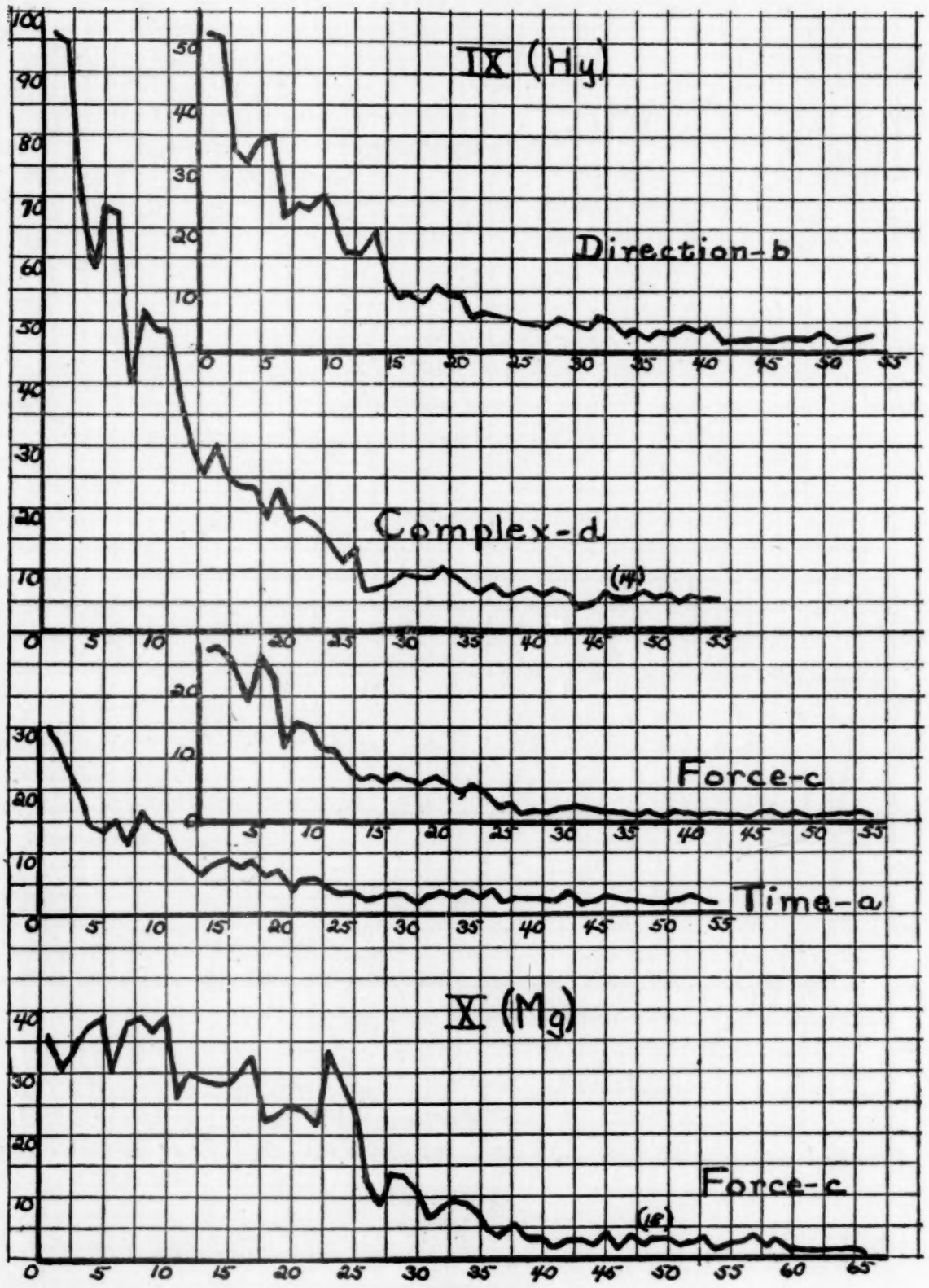

PLATE VI

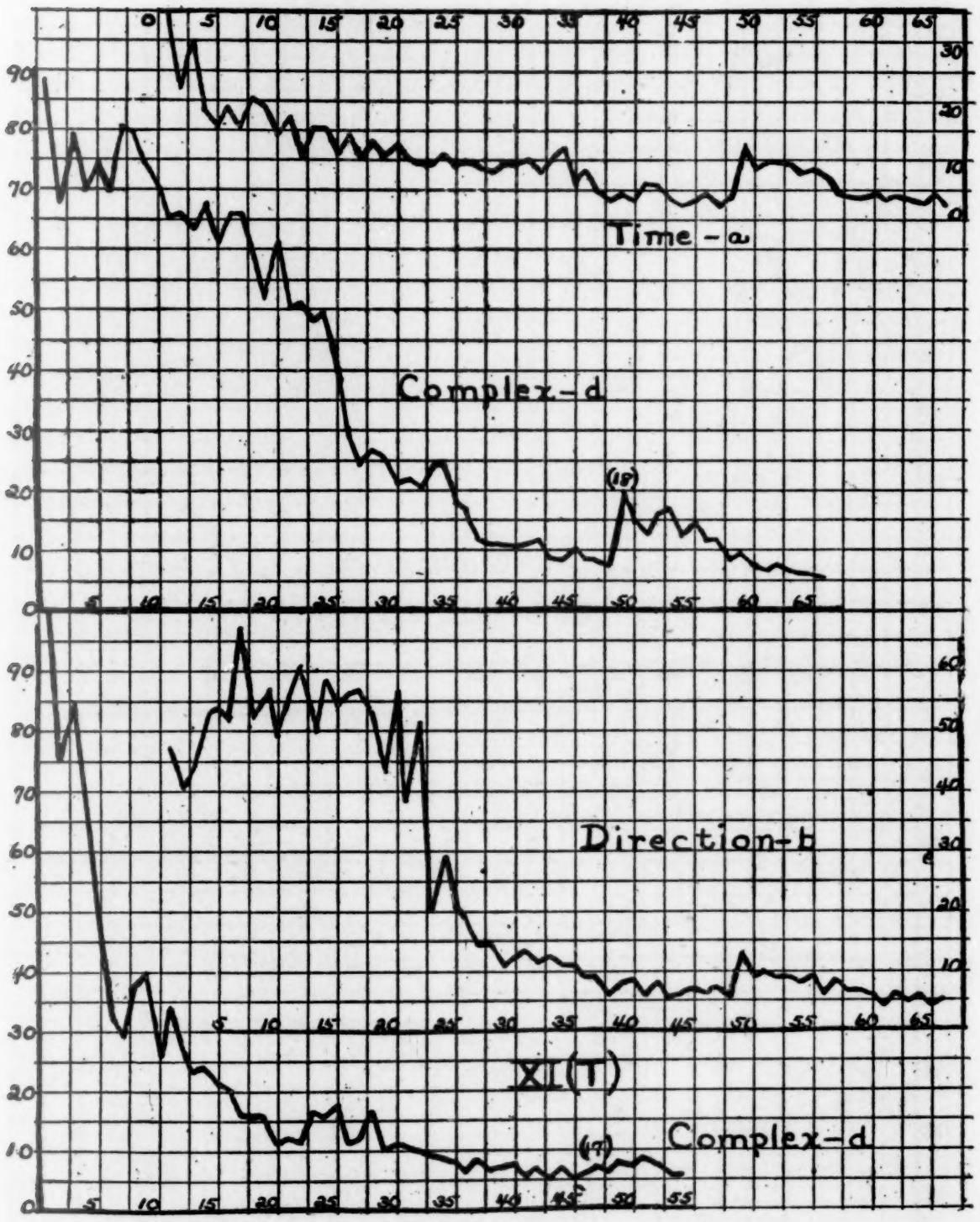

PLATE VII

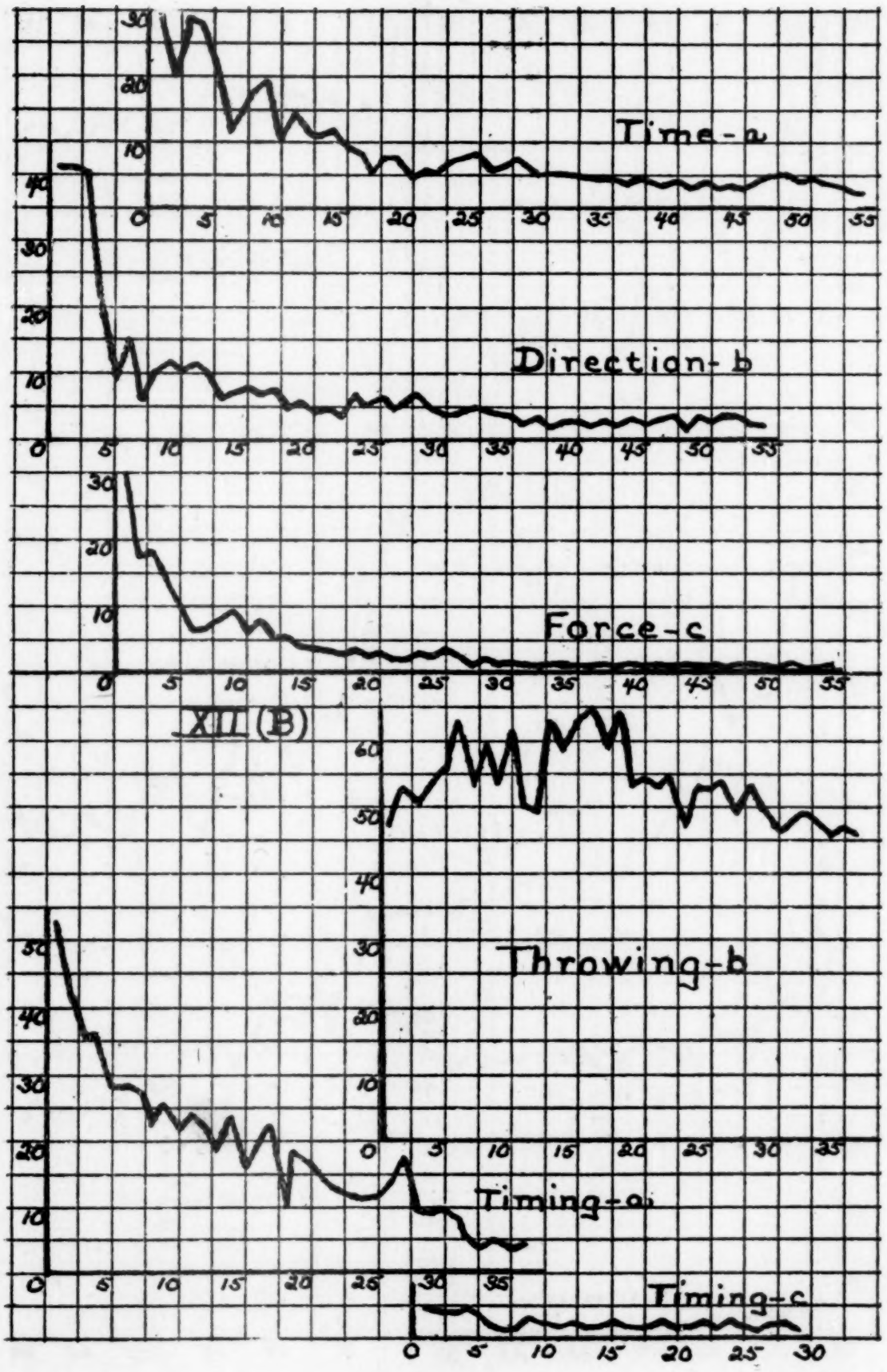

PLATE VIII

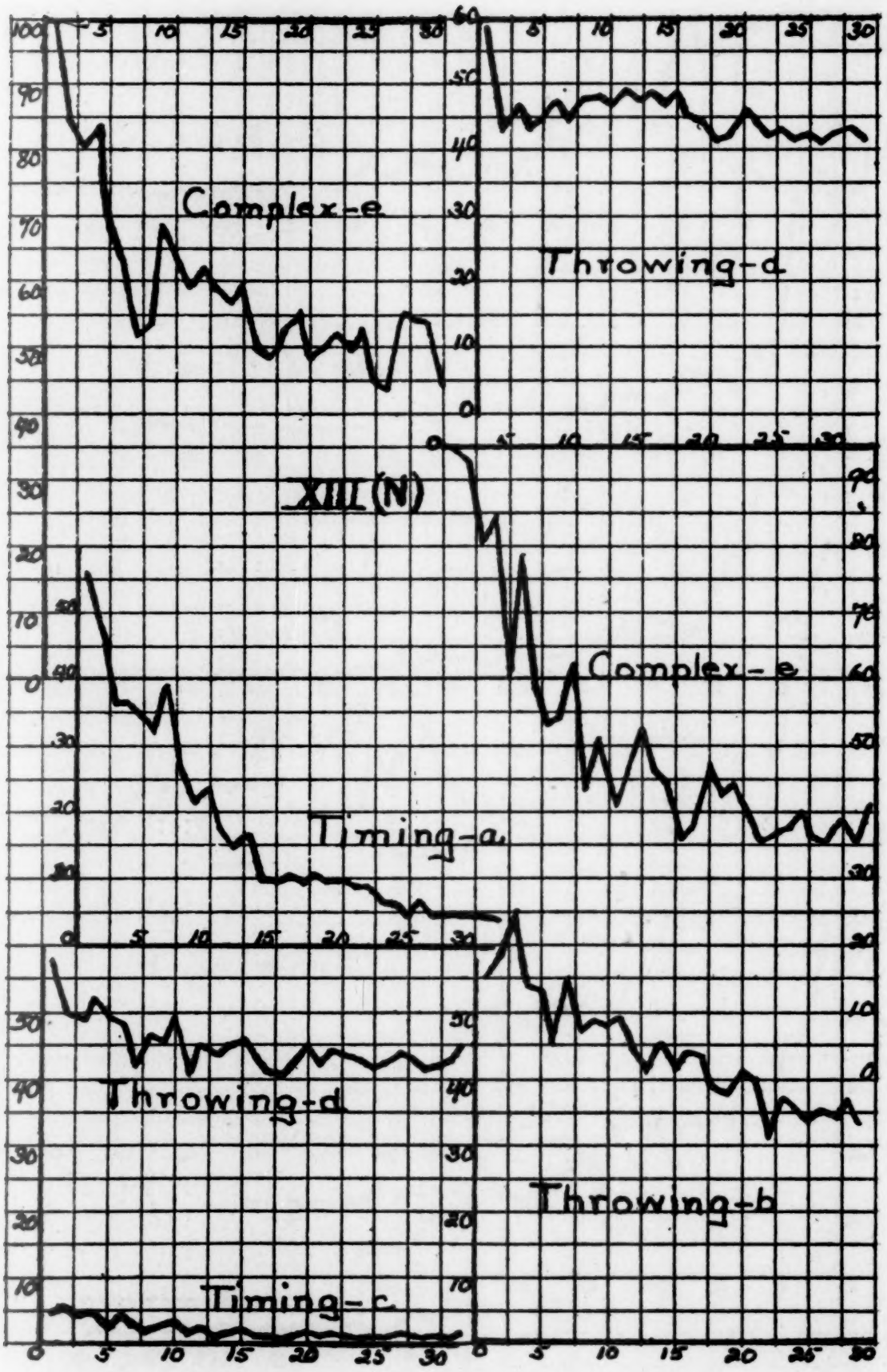
Complex-e
Throwing-d
XIII (N)
Complex-e
Timing-a
Throwing-d
Throwing-b
Timing-c

PLATE IX

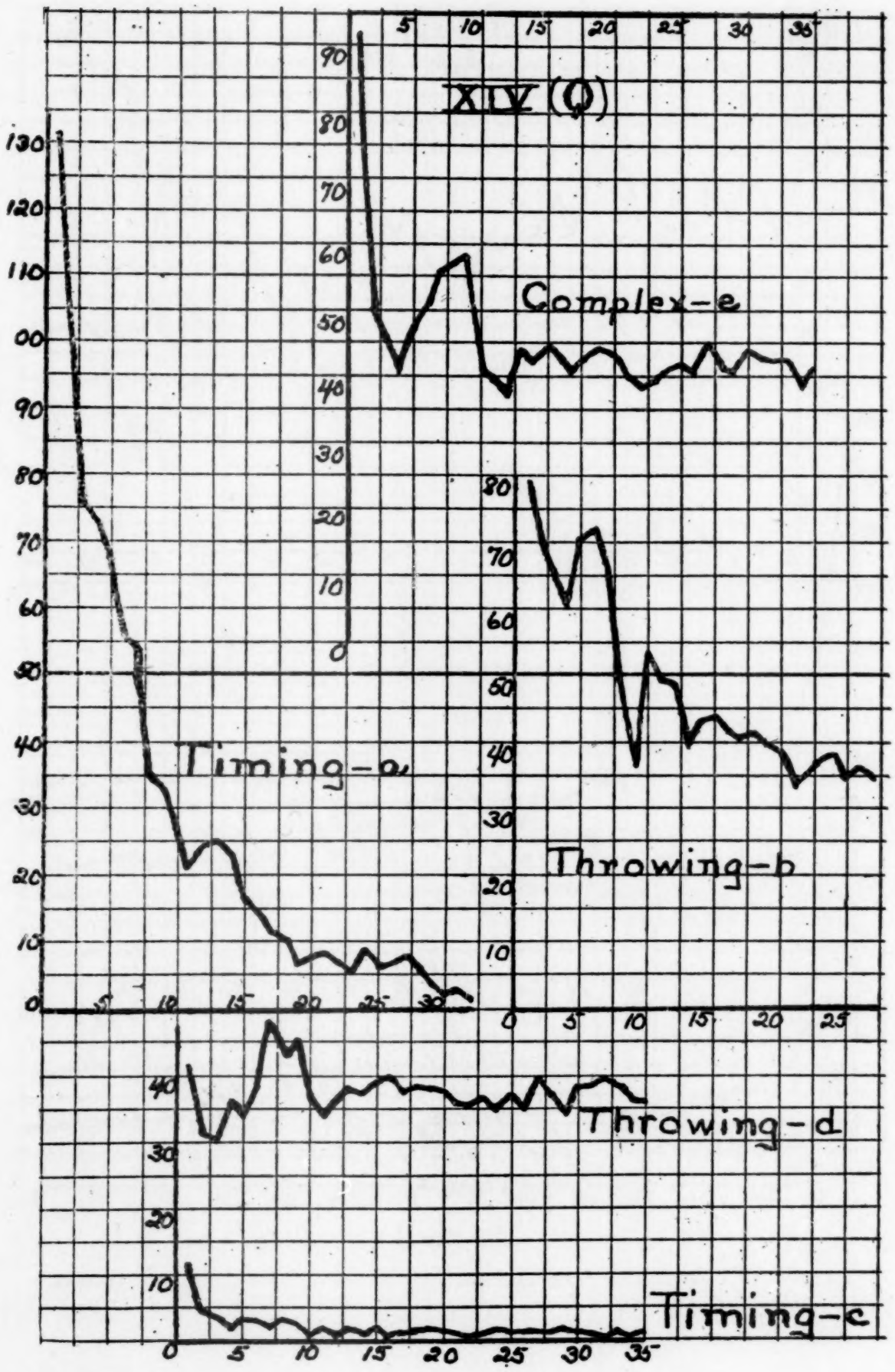

PLATE X

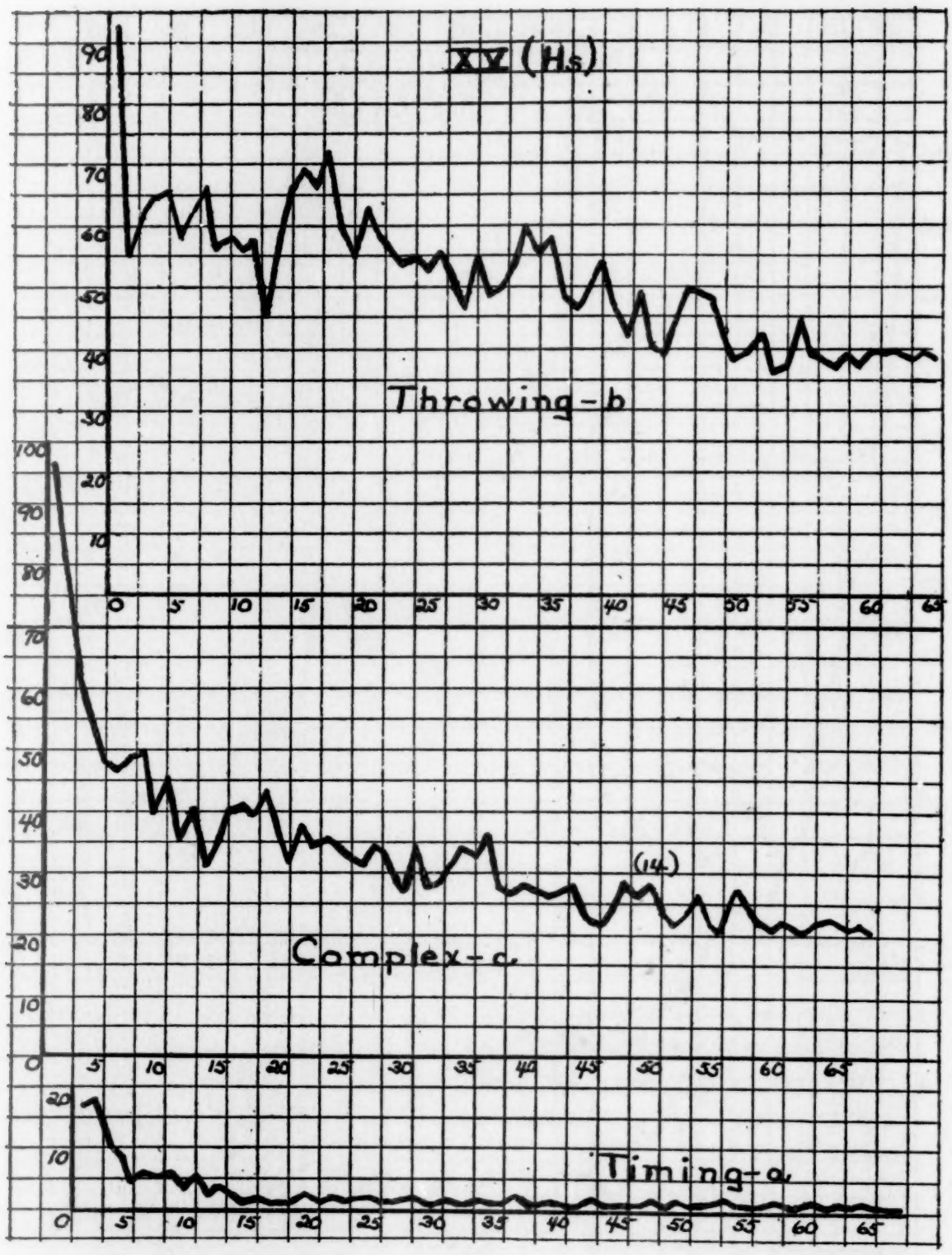

PLATE XI

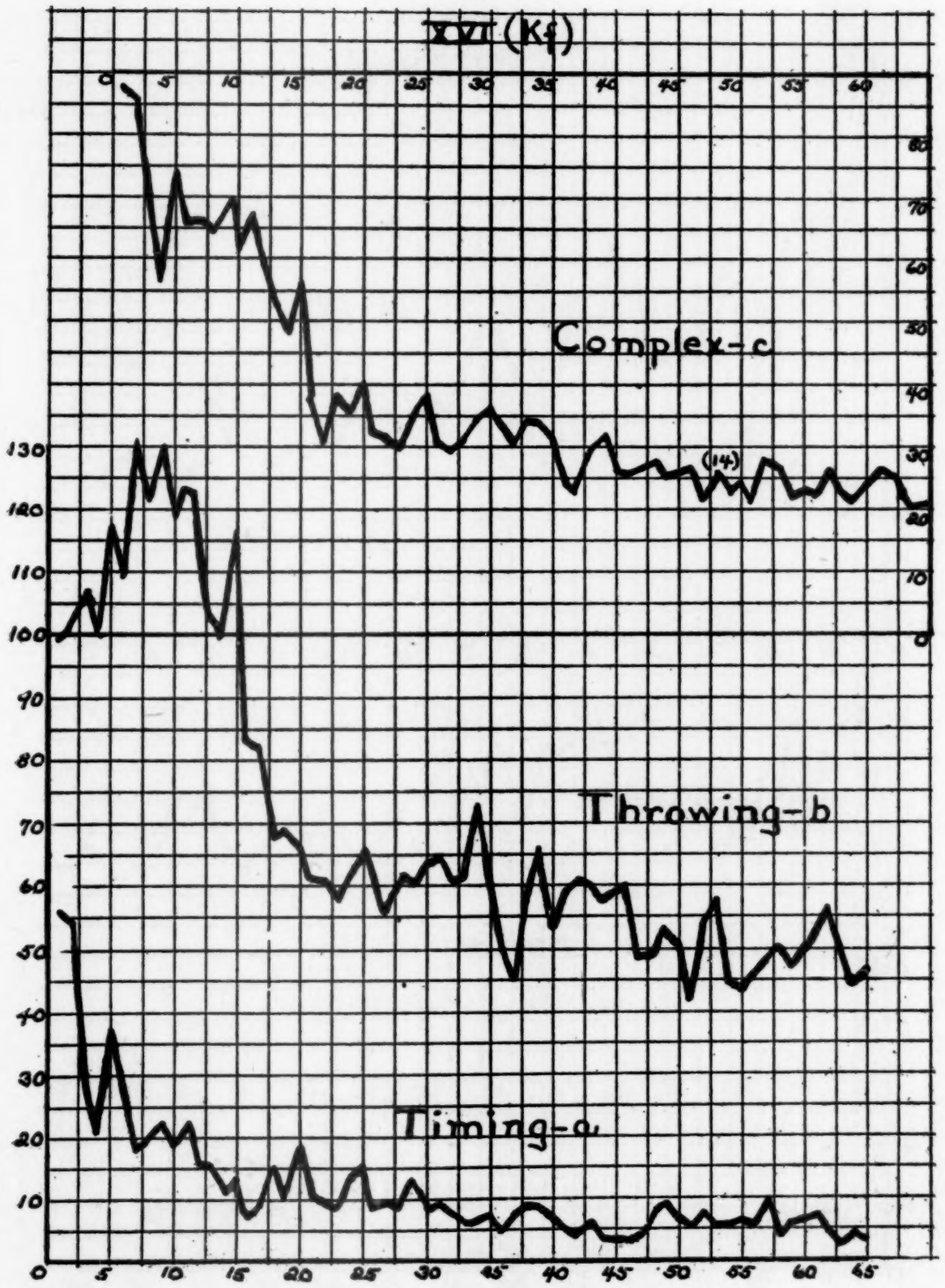

PLATE XII

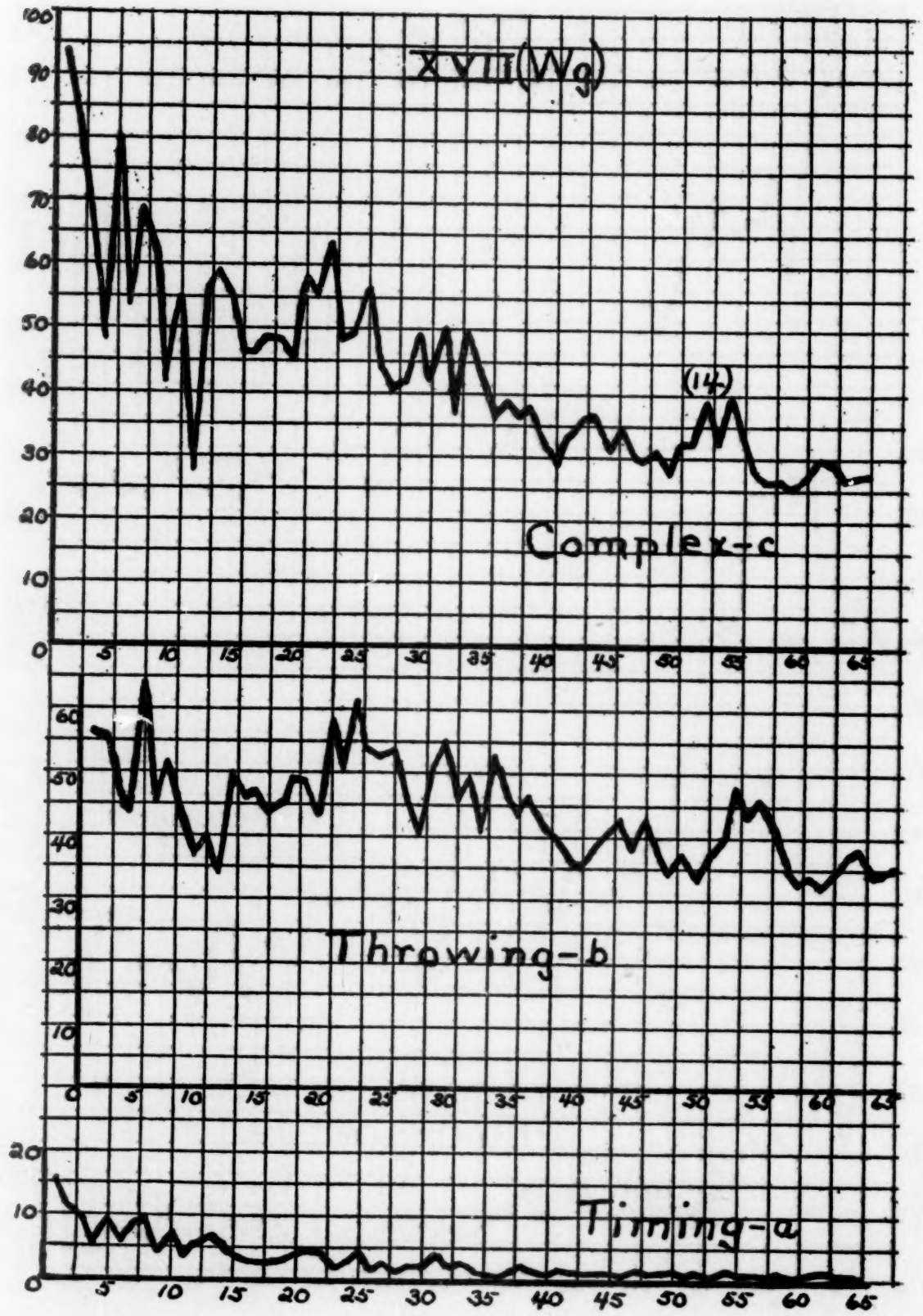

PLATE XIII